Lake Superior
Mining Institute

PROCEEDINGS—1894

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PROCEEDINGS

OF THE

LAKE SUPERIOR MINING INSTITUTE

SECOND ANNUAL MEETING

MARCH, 1894

VOL. II

PUBLISHED BY THE INSTITUTE

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DARIUS D. THORP,
LANSING, - MICH.

OFFICERS OF THE

LAKE SUPERIOR MINING INSTITUTE, 1894.

PRESIDENT.

	Terms expire in March—
J. Parke Channing	1895

VICE-PRESIDENTS.

John T. Jones	1895
F. P. Mills	1895
Graham Pope	1895
W. J. Olcott	1896
R. A. Parker	1896

MANAGERS.

W. Fitch	1895
John Duncan	1895
C. M. Boss	1896
O. C. Davidson	1896
M. E. Wadsworth	1896

TREASURER.

A. C. Lane	1895

SECRETARY.

F. W. Denton	1895

(These officers constitute the council.)

HONORARY MEMBERS.

Raphael Pumpelly. T. B. Brooks. J. D. Whitney.

ACTIVE MEMBERS.

Alvar, G. A., Commonwealth, Wis.
Abeel, Geo. H., Hurley, Wis.
Adams, John Q., Negaunee, Mich.
Barker, John, Iron Mountain, Mich.
Barnett, James H., Iron Belt, Wis.
Beattie, S. T., Florence, Wis.
Bokman, Chas. E., Iron Mountain, Mich.
Bond, William, Vulcan, Mich
Boss, C. M, Bessemer, Mich.
Bosson, F. N., Calumet, Mich.
Brady, Samuel, Detroit, Mich.
Breitung, Edward N., Marquette, Mich.
Brown, E. F., Iron Mountain, Mich.
Bullock, M. C., Chicago, Ill.
Burt, M. W., Ironwood, Mich.
Butler, Wm. C., Everett, Wash.
Bradt, E. F., Ishpeming, Mich.
Brett, Henry, Calumet, Mich.
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Chadbourne, T. L., Houghton, Mich.
Channing, J. Parke, Calumet, Mich.
Childs, Wm. A., Calumet, Mich.
Cole, T. F., Negaunee, Mich.
Conro, Albert, Milwaukee, Wis.
Cooper, James B., South Lake Linden, Mich.
Copeland, F., Vulcan, Mich.
Coventry, F. L., Commonwealth, Wis.
Croze, W. W. J., Negaunee, Mich.
Channing, R. H., Jr., Iron Mountain, Mich.
Curnow, J. W., Vulcan, Mich.
Curry, S. S., Ironwood, Mich.
Daniell, John, Opechee, Mich.
Davidson, O. C., Commonwealth, Wis.
Denton, F. W., Houghton, Mich.
Dee, James R., Houghton, Mich.
Dickman, R. N., No. 71 Atwater bldg., Cleveland, Ohio.
Downing, W. H., Ishpeming, Mich.
Duncan, John, Calumet, Mich.
Dunham, L. E., Ashland, Wis.
Dunn, W. A., Houghton, Mich.
Dyer, H., Ishpeming, Mich.
Dengler, Theo., Atlantic Mine, Mich
Ellard, H. F., Commonwealth, Wis.
Edwards, A. D., Atlantic Mine, Mich.
Fairbairn, C. T., Ishpeming, Mich.
Fitch, Walter, Beacon, Mich.
Fitch, W. F., Marquette, Mich.
Farrel, Austin, Marquette, Mich.
Goudie, Jas. H., Ironwood, Mich.
Gibbs, Geo., Milwaukee, Wis.
Gibson, Matthew, Champion, Mich.
Gibson, Thoburn, Amasa, Mich.
Green, R. B., Virginia, St. Louis Co., Minn.
Goldsworthy, Martin, Iron Mountain, Mich.
Goodsell, B. W., 20 W. Lake st., Chicago, Ill.
Greenwood, Geo., Calumet, Mich.
Hanna, L. C., Cleveland, Ohio.
Harris, John L., Hancock, Mich.
Harris, S. B., Hancock, Mich.
Hearding, J. H., Ironwood, Mich.
Heath, Geo. L., South Lake Linden, Mich.
Hodge, Chas. J., Houghton, Mich.
Haselton, H. S., Milwaukee, Wis.
Hendrick, C. E., Ishpeming, Mich.
Hinton, Francis, Milwaukee, Wis.
Hellberg, Gustaf A., Norway, Mich.
Hocking, T. H., Amasa, Iron Co., Mich.
Holland, James, Iron Mountain, Mich.
Holley, S. H., Marquette, Mich.
Hollis, H. L., No. 1232 Rookery bldg., Chicago, Ill.
Hoatson, Thos., Calumet, Mich.
Hooper, J. K., Crystal Falls, Mich.
Hopkins, E. W., Commonwealth, Wis.
Houghton, Jacob, No. 51 East Elizabeth st., Detroit, Mich.
Hubbard, Lucius, L., Houghton, Mich.
Hulst, Nelson P., Milwaukee, Wis.
Hotson, W. E., Florence, Wis.
Jones, Jno. T., Iron Mountain, Mich.

V.

DUES.

The dues of members shall be five dollars, payable upon their election, and five dollars per annum thereafter, payable in advance at or before the annual meeting. Honorary members shall not be liable to dues. Any member not in arrears may b come a life member by the payment of fifty dollars at one time, and shall not be liable thereafter to annual dues. Any member in arrears may, at the discretion of the council, be deprived of the receipt of publications or be stricken from the list of members when in arrears six months; PROVIDED, that he may be restored to membership by the council on the payment of all arrears, or by re-election after an interval of three years.

VI.

OFFICERS.

There shall be a president, five vice-Presidents, five managers, a secretary and a treasurer, and these officers shall constitute the council.

VII.

TERM OF OFFICE.

The president, secretary and treasurer shall be elected for one year and the vice-presidents and managers for two years, except that at the first election two vice-presidents and three managers shall be elected for only one year. No president, vice-president or manager shall be eligible for immediate re-election to the same office at the expiration of the term for which he was elected. The term of office shall continne until the adjournment of the meeting at which their successors are elected.

Vacancies in the council, whether by death, resignation, or the failure for one year to attend the council meetings, or to perform the duties of the office, shall be filled by the appointment of the council, and any person so appointed shall hold office for the remainder of the term for which his predecessor was elected or appointed; PROVIDED, that such appointment shall not render him ineligible at the next election.

VIII.

DUTIES OF OFFICERS.

All the affairs of the Institute shall be managed by the council, except the selection of the place of holding regular meetings.

The duties of all officers shall be such as usually pertain to their offices, or may be delegated to them by the council.

The council may in its discretion require bonds to be given by the treasurer, and may allow the secretary such compensation for his services as they deem proper.

At each annual meeting the council shall make a report of proceedings to the Institute, together with a financial statement.

Five members of the council shall constitute a quorum; but the council may appoint an executive committee, or business may be transacted at a regularly called meeting of the council, at which less than a quorum is present, subject to the approval of a majority of the council, subsequently given in writing to the secretary and recorded by him with the minutes.

There shall be a meeting of the council at every regular meeting of the Institute, and at such other times as they determine.

IX.

ELECTION OF OFFICERS.

Any five members, not in arrears, may nominate and present to the secretary over their signatures, at least thirty days before the annual meeting, the names of such candidates as they may select for offices falling under the rules. The council, or a committee thereof duly authorized for the purpose, may also make similar nominations. The assent of the nominees shall have been secured in all cases.

Not less than two weeks prior to the annual meeting, the secretary shall mail to all members not in arrears a list of all nominations made, and the number of officers to be voted for in the form of a letter ballot. Each member may vote either by striking from or adding to the names upon the list, leaving names not exceeding in number the officers to be elected, or by preparing a new list, signing the ballot with his name, and either mailing it to the secretary, or presenting it in person at the annual meeting.

In case nominations are not made thirty days prior to the date of the annual meeting for all the offices becoming vacant under the rules, nominations for such offices may be made at the said meeting by five members not in arrears, and an election held by written or printed ballot.

The ballots in either case shall be received and examined by three tellers, appointed at the annual meeting by the presiding officer; and the persons who shall have received the greatest number of votes for the several offices shall be declared elected. The ballots shall be destroyed, and a list of the elected officers, certified by the tellers, shall be preserved by the secretary.

X.

MEETINGS.

The annual meeting of the Institute shall be held on the first Wednesday of March, and a fall meeting shall be held on the first Wednesday in September. The Institute may at a regular meeting select the place for holding the next regular meeting. If no place is selected by the Institute, it shall be done by the council.

Special meetings may be called whenever the council may see fit; and the secretary shall call a special meeting at the written request of twenty or more members. No other business shall be transacted at a special meeting than that for which it was called.

Notices of all meetings shall be mailed to all members, at least thirty days in advance, with a statement of the business to be transacted, papers to be read, topics for discussion and excursions proposed.

No vote shall be taken at any meeting on any question not pertaining to the business of conducting the Institute.

Every question that shall properly come before any meeting of the Institute, shall be decided, unless otherwise provided for in these rules, by the votes of a majority of the members then present.

Any member may introduce a stranger to any regular meeting; but the latter shall not take part in the proceedings without the consent of the meeting.

XI.

PAPERS AND PUBLICATIONS.

Any member may read a paper at any regular meeting of the Institute, provided the same shall have been submitted to and approved by the council, or a committee duly authorized by it for that purpose prior to such meeting. All papers shall become the property of the Institute on their acceptance, and with the discussion thereon, shall subsequently be published for distribution. The number, form and distribution of all publications shall be under the control of the council.

The Institute is not, as a body, responsible for the statements of facts or opinion advanced in papers or discussions at its meetings, and it is understood, that papers and discussions should not include personalities, or matters relating to politics, or purely to trade.

XII.

AMENDMENTS.

These rules may be amended by a two-thirds vote taken by letter ballot in the same manner as is provided for the election of officers by letter ballot, PROVIDED, that written notice of the proposed amendment shall have been given at a previous meeting.

PROCEEDINGS OF THE SECOND ANNUAL MEETING.

The meeting opened with a reception at the Michigan Mining School in Houghton, at three P. M., March 7.

The members were welcomed by the Hon. Jay A. Hubbell, chairman of the Board of Control of the Mining School, after which the members were conducted through the buildings.

In the evening a session, for the reading of papers and transaction of business, was held at the Armory Opera House in Houghton, President Nelson P. Hulst, presiding.

After the passage of a suitable motion, the President appointed the following committee to nominate candidates for the offices about to become vacant: R. A. Parker, M. W. Burt, Per Larson, H. V. Winchell, Wm. A. Parnall, Graham Pope.

Mr. Graham Pope was then called to the chair, and President Hulst delivered his address.

The following papers were then read in part or in full:

"Two New Geological Cross Sections of Keweenaw Point," by Dr. L. L. Hubbard, State Geologist.

In connection with his paper, Dr. Hubbard briefly outlined the main geological features of Keweenaw Point.

"Historical Sketch of the Discovery of Mineral Deposits in the Lake Superior Region," by Mr. H. V. Winchell.

Prof. F. W. Denton showed some underground mining views by means of a projecting lantern.

The meeting then adjourned until the next evening.

SECOND EVENING SESSION.

The meeting was opened at 8 P. M., President Hulst presiding, by the reading of a paper by Mr. J. Parke Channing on the "Curvature of Diamond Drill Holes." After the discussion of this paper, Prof. F. F. Sharpless described "Ore Dressing on Lake Superior," with the aid of lantern slides.

Prof. Sharpless was followed by Captain Wm. Bond, who read a paper on the "Sinking of 'C' Shaft, West Vulcan."

Mr. Wm. Kelly then described, by means of large drawings, a pocket stop in use at the Vulcan mines.

After some discussion of this pocket stop, a short recess was taken to permit visitors who were not members of the Institute to withdraw.

The Institute then transacted the following business:

The Secretary read the following report of the council to the Institute:

REPORT OF THE COUNCIL.

During the past year, the first of the organization of the Institute, the active membership has reached one hundred and twenty-two. Owing to the recent resignation of one member, due to his change of residence and occupation, the number of active members is now one hundred and twenty-one.

There are no honorary, associate or life members. Seven hundred and fifty copies of the published proceedings have been distributed free to members and others.

Four hundred and fifty copies remain in the possession of the Institute.

The council has decided in future to charge non-members five dollars per year for the publications of the Institute.

The Secretary's salary for the past year has been fixed at one hundred dollars.

It has been decided that authors of papers shall be furnished with extra copies of their papers at cost.

The council has also decided to withhold the papers of the Institute from publication by technical and other journals, until after they have been issued by the Institute.

Authors are reminded that by article XI of the Rules, their papers become the property of the Institute.

As the business interests throughout the several iron mining districts were in a most unhappy condition last September, and as an attempt to hold a meeting of the Institute would probably have been detrimental to the Institute, the council unanimously decided to pass the September meeting.

The following is a statement of the receipts and expenditures for the year, not including the expenses of the present meeting.

Receipts.

Dues from 122 members for 1893		$610 00	
Dues from 1 member for 1894		5 00	
Total receipts		$615 00	$615 00

Expenditures.

PRINTING.

First edition Proceedings, 700 copies		$87 94	
Second edition Proceedings, 500 copies		60 00	
Stationery		9 75	
Blanks		11 75	
Circulars, August, 1893		2 10	
Total printing		$171 54	

OTHER EXPENSES.

Inaugural Meeting at Iron Mountain:			
Printing	$15 25		
Stenographer	5 00		
Postage	30 45		
Clerical help	2 00		
Total	$52 70	52 70	
Postage on Proceedings, circulars, etc., to date		39 00	
Express		2 35	
Clerical help		7 00	
Wrapping 700 Proceedings and one Index		7 25	
Ledger and Journal books		3 00	
Card catalogue, letter files and cards		6 46	
Secretary's salary for 1893-94		100 00	
Exchange on drafts		60	
Total expenditures		$389 90	389 90
Balance in the treasury			$225 10

The report of the council was approved. The following gentlemen were then elected members of the Institute, having been duly recommended by the council:

Honorary Members.

Raphael Pumpelly. T. B. Brooks. J. D. Whitney.

Active Members.

C. E. Hendrick	Ishpeming, Mich.
W. H. Downing	Ishpeming, Mich.
Chas. E. Bokman	Iron Mountain, Mich.
James M. Merton	Calumet, Mich.
Wm. A. Childs	Calumet, Mich.
Henry Brett	Calumet, Mich.
George Greenwood	Calumet, Mich.
Hillary Messimer	Calumet, Mich.
James Ramsay	Calumet, Mich.
Thos. Hoatson	Calumet, Mich.
T. W. Milligan	Calumet, Mich.
F. N. Bosson	Calumet, Mich.
Wm. A. Parker	Chicago, Ill.
M. C. Bullock	Chicago, Ill.
Frank Hinton	Milwaukee, Wis.
S. S. Curry	Ironwood, Mich.
Hyatt Haselton	Milwaukee, Wis.
W. D. Van Dyke	Milwaukee, Wis.
L. J. Pettit	Milwaukee, Wis.
Austin Farrell	Negaunee, Mich.
A. D. Edwards	Atlantic Mine, Mich.
Theodore Dengler	Atlantic Mine, Mich.
B. W. Goodsell	Chicago, Ill.
J. U. Curnow	Vulcan, Mich.

The nominating committee then made its report as follows:

President—J. Parke Channing.

Vice-Presidents—W. J. Olcott and R. A. Parker.

Managers—C. M. Boss, O. C. Davidson, M. E. Wadsworth.

Treasurer—A. C. Lane.

Secretary—F. W. Denton.

Officers nominated by the committee were duly elected. After the passage of a vote of thanks to the mining companies and others, "who have entertained us so cordially," the meeting adjourned.

REGISTER OF NON-RESIDENT MEMBERS WHO ATTENDED THE MEETING.

E. F. Bradt.	C. M. Boss.	Per Larsson.
Wm. Kelly.	J. M. Vickers.	H. B. Paull.
T. McNamara.	R. C. Knight.	H. G. Rothwell.
Wm. Bond.	G. H. Hocking.	W. G. Rattle.
Wm. G. Mather.	F. P. Mills.	H. V. Winchell.
M. W. Burt.	Gus. Alvar.	Peter Pascoe.
W. E. Tyler.	R. A. Parker.	B. W. Goodsell.
Jas. MacNaughton.	O. C. Davidson.	E. W. Hopkins.
F. L. Coventry.	W. E. Hotson.	E. F. Brown.
S. T. Beattie.	W. Fitch.	W. D. Van Dyke.
Nelson P. Hulst.	J. B. Knight.	J. R. Wood.
J. H. McLean.	C. S. Simpson.	S. Parnall.

EXCURSIONS.

On Thursday morning a special train took the members of the Institute to Calumet, where they were received by Messrs. John Duncan and J. Parke Channing who escorted the party through the surface works of the Calumet and Hecla mines.

A train provided by the company took the party back to the hotel where lunch was served by the company.

Again boarding the train so kindly furnished by the Calumet and Hecla management, the visitors were taken to the Red Jacket vertical shaft of the Calumet and Hecla mines.

From the vertical shaft the party was taken to the Tamarack Mine, where Mr. Wm. E. Parnall received it. After inspecting the Tamarack works a visit was made to the North Tamarack shafts, whence the party returned to Houghton.

On Friday morning a special train carried the members to the Calumet and Hecla smelting works, where Mr. J. B. Cooper received them.

From the smelting works a train provided by the Calumet and Hecla company took the party to the Calumet and Hecla mills, where Mr. F. G. Coggin received it.

Taking the train again, visits were made to the Tamarack and Quincy mills. The party returned to Houghton in time to take the 2 P. M. train home.

The local mining companies extended an invitation to the visitors to remain longer for the purpose of going underground, but none were able to accept.

For the benefit and guidance of the visitors, a pamphlet was prepared by the Secretary, giving maps of the prominent mining properties and information concerning their equipment. All local members were on the reception committee, and strove in every way to make the excursion a success, and their efforts were highly appreciated by the visiting members.

PRESIDENT'S ADDRESS.

As there lack but a few months to the full half century since iron ore was discovered by white men in this Upper Peninsula of Michigan and a like period since the first active steps were taken by white men to develop the copper mines of the district, this seems an especially fitting occasion for asking the Institute to follow me in a retrospect of the remarkable period.

Prior to 1844, the region was a trackless wilderness, except as the Indian's and trapper's trails threaded it. In these previous years, occasionally a report from trappers and fur dealers reached the far-away States, like a tradition, that pure copper in masses was to be found within its fastnesses, which confirmed the published statements of the early missionaries who had penetrated the region. Only the most venturesome, however, were drawn to its inhospitable shores. The whole region so little known was esteemed of little value. It was not until the report of Jacob Houghton, the pioneer geologist of the region, proclaimed to the world its riches in copper, that much attention was accorded to it.

What is now called the Upper Peninsula of Michigan was at one time offered by Congress to the Territory of Michigan to requite her for the loss of a little strip of a few square miles in area, bordering on Lake Erie, which was claimed also and subsequently secured by the State of Ohio. The Territorial Convention of Michigan promptly rejected the offer of the wild and supposed worthless tract. When it became evident that Statehood, which was so eagerly desired by the people, was quite dependent upon the acceptance of this wilderness tract, the convention wisely but ungraciously agreed to include this jumping off place within the state boundaries; taking what comfort there might be in the old adage that "half a loaf was better than no bread." As early as 1843 the region had been thrown open by congress to settlement and a few intrepid miners or explorers had located themselves upon some of the valuable mining lands The following year the number of prospectors was largely increased and mining operations fairly begun. The finding of many stray masses of native copper, when advertised in the older states, aroused such excitement, that the year of 1845 saw the copper region for the whole length of Keweenaw point and southwesterly to Gogebic lake, overrun with eager prospectors.

As the prizes were few, the very natural relapse followed, and the region became almost deserted in 1847. It is stated by Whitney that in that year only a half dozen companies had active existence as miners in the region. Among the throngs of prospectors who had set out in 1845 to search for copper was a party from Jackson in the lower part of the state. At the Sault they fell in with an Indian half-breed who volunteered to pilot them to a bed of outcropping iron ore. This pilot failing them in the search for it, they secured an Indian chief at Copper Harbor who guided them to an outcrop of the iron ore from which has been developed the well known Jackson Mine. Previous to this, however, U. S. surveyors in the prosecution of a survey in the region had discovered beds of iron ore near this Jackson Mine outcrop, which entitles them to the honor of being the first discoverers of this great field of merchantable iron ore, which for nearly forty years has poured forth an ever-increasing supply to meet the country's demands.

The first iron ore which the region produced was taken from the Jackson mine in 1846. In February, 1848, the first iron manufactured in the Lake Superior region was made at the Jackson forge, which was located at a convenient water power on Carp River, some three miles distant from the mine. Here, as elsewhere, throughout the country in that comparatively early day, the miners of iron ore were also forge or furnace proprietors, and their aim was to reduce it, as nearly on the spot as possible, to merchantable iron. It was the prevailing practice of the time, especially where the fuel was charcoal. In the anthracite and bituminous coal regions, the hitherto joint industry of mining and smelting or forging had already awakened to the fact, that economy in the production of iron compelled the location of furnaces near the permanent supply of these newly applied fuels. The necessity of a mixture of ores to secure special qualities of pig iron further emphasized the location of furnaces at points where these rich new fuels were abundant and cheap, since the desired ores for the mixtures required being found at places separated from one another entailed an unavoidable expense in transportation. As soon as the Lake Superior ores were known, their richness and purity were enticing factors to furnace men west of the Alleghanies, even those as far distant from the new region as New Castle, Pa. In 1850 a trial lot of five tons reached this smelting point. Its reduction to blooms there, advertised quickly the remarkable quality of the metal the ores would produce. In 1852 some 70 tons, at great cost of transportation and rehandling, was carried to Sharon, Pa. It was not, however, until 1855, when the Sault Canal was completed sufficiently to allow the passage of vessels, that regular shipments of iron ore began to be made to lower lake ports. It was in fact the pressing need of the Lake Superior ores for the furnaces of Ohio and Pennsylvania, more than all things else, which hastened the completion of this great water-way. Without a navigable channel, the iron ores of the region were practically valueless, since they could not bear the enhanced cost brought about by rehandling at the Sault. In the meantime, before the completion of the canal, the product of the iron mines was wholly worked up in the forges of the district. But with no means of economically transporting the blooms to a market the industry languished. No near market existed in any direction for the product.

Thus shut in by themselves and entirely isolated from the world for half a year, regularly, by the rigors of winter, there was little of promise to the pioneer miners and forge proprietors. Under such vicissitudes they were having dearly bought experience. With the advent of the civil war and a protective tariff, an enhanced price of iron was brought about, which infused new life into the mine owners.

The canal having been completed and a railroad having been built from Marquette to the mines, the problem of economical transportation was solved. Then immediate and great demands were made upon the region for its incomparable ores, which started it on the highway of a grand success.

The copper region had had more of success in its undertakings during this period which had so tried the iron mining enterprises.

The Cliff, Central, Minnesota and other mines had paid considerable dividends, and as a consequence mining was conducted vigorously, not only by these mining companies, but by others which hoped for a like success.

As we look back to the beginning of this half century span under consideration, we see everywhere throughout our country how primitive was the art of mining compared with its present attainments. The hammer, drill, pick and gad were the miner's chief equipment. At a very few mines, excepting the colleries, had steam hoisting engines been installed. Wire hoisting ropes were not yet introduced, hempen cables and chains serving the purpose. Wheelbarrows and buckets or kibbles were in universal use. Mining enterprises were not, however, new to the country The records of early colonial times make mention of many mines which had been in long continuous operation.

So in 1844 more or less of mining activity was to be witnessed in nearly every state in the union. Copper sulphide ores were the products of long wrought mines in several of the eastern and southern states. Their workings were as a consequence more extensive than those of any other mines; the deepest having attained a depth of between 300 and 400 feet. The sandstones of New Jersey had furnished some small masses of native copper of a total weight of nearly a ton. Gold mining at this period had been very active along the Appalachian range, in Virginia, the two Carolinas and Georgia. It was an industry of nearly twenty years standing. For the most part it was placer mining. Shaft sinking had been carried to shallow depths in a few of the mines where the rock was pretty well disintegrated. In the estimate of value of the mines the gold was, more often than otherwise, calculated by the yield of a bushel of earth which was the unit of measure. Lead or lead silver mines were wrought in several of the New England, middle and southern states. Those of Rossie, New York, were the most extensive.

Whitney, writing of this period, states that although these Rossie mines had been wrought with the greatest activity, yet it was in entire ignorance of the first principles of mining. The lead mines of Wisconsin and Missouri were famous at this time.

But the most considerable of the metal mining interests of the country were those of iron. Scarcely a state but had its forges and charcoal furnace plants relying on the immediate neighborhood for supplies of fuel and ore. The twin industry, mining and smelting, or reduction into blooms was a legacy from early colonial times. For the most part the market was no more extended than the immediately adjacent territory since the product of any plant was ridiculously small. As late as 1849 the charcoal pig iron production of Vermont was only 4,000 tons annually from 10 furnaces averaging but little above a ton per day per furnace. In the same year Western Massachusetts and Western Connecticut each made a product not exceeding 12,000 tons. The largest iron mining states were New York, Pennsylvania and Tennessee, taking rank in the order named. In New York the ores of Clinton Co., rich magnetics, were the most celebrated and largely used in the forges. Mining them had reached the considerable depth of 260 feet in 1842. In 1849 the largest bloomery or collection of forges, 21 in number and requiring a supply of 50,000 tons of ore annually, was located in this county. It was rarely, however, that iron mines were more than shallow open pits. Of metal mining in general at that time, Whitney says "Up to this time the attempts at regular mining had been few and far between. Excavations had been made in rock but no extensive, permanent and productive mines had been opened. In the Wisconsin and Missouri region systematic work and enlarged plans were not indispensable to mining lead ores with success. In other parts of the United States there had never been encouragement enough or sufficient mining skill to direct the investment of any considerable amount of capital into that channel."

The discovery of gold in California in 1848 started the mining spirit aflame throughout our nation, even throughout the civilized world. The impulse given by this discovery has moved with ever wider-reaching influence, until no one can measure its limits. Thither came people from every corner of the earth, all eager to secure a portion of the wealth that glittered in the stream beds. The easily won placer gold permitted the clumsiest shoveler to stand on a par with the miner of experience. Brute strength discounted the skill of the miner so long as the gold continued plentiful in the sands of the streams. When, however, the yield of stream gold became scanty, the ubiquitous yankee stepped in with his invention of the easily contrived "little giant" nozzle in order to use the power of a head of water in placer mining, from which immediately sprung the new art of hydraulic mining. Then began the washing away of the mountain sides and the construction of ditches of many miles in length in order to secure a great volume of water with lofty head, whereby an irresistible stream could be turned upon gravel banks and the ancient river beds, which were almost of the nature of solid rock, so firmly were their sands and gravels cemented together. This new method of mining, with the conditions all favorable, was conducted with such a degree of economy that as little as three cents worth of gold to the cubic yard of washed gravel brought great fortunes to the hydraulic mining companies. So profitable a method of mining meant, however, the washing away annually of many millions of cubic yards of earth which in a few years began to bury agricultural lands in the valleys under floods of gravel. In a brief time the possibilities of their increase became so threatening that state enactment of debris laws effectually brought an end to the most of this style of mining in California.

From placer mining to quartz mining the parent source of the placer gold was a ready step for the California miners.

Even as early as 1853 some of these more hopeful miners had hammered away for several years at the hard quartz ledges without having any pecuniary success. Lack of success was not so much ascribed to the mining as to the inefficient stamp mills. The miners, already infused with the American spirit of ingenuity, applied themselves to the gold stamp mill problem, adding to it here, eliminating parts from there, until the California gold stamp mill stood forth in its entirety, a splendid child, which its parent, the old Cornish stamp mill, could hardly claim as its offspring.

In Colorado where conditions were different, modifications of the California stamp mill were made, and in Nevada where silver and silver gold ores were plentiful other modifications were made, which brought into existence the American silver mill with its complex pan process. In the search for further economies, with fuel scarce and expensive, the miner and mill man turned to the easily available high head water power of the lofty ditches furnishing water to the hydraulic miner, for a cheap power for his newly created stamp mill. The old impact or hurdy-gurdy wheel was seized upon, trimmed of its crudities and furnished with new pockets. It then came forth as the admirable Pelton wheel, which having small diameter and supplied with water under great pressure through an insignificant little nozzle, was able of itself to furnish most reliably hundreds of most manageable horse power.

One of the most conspicuous of the results flowing from this activity in mining, which began in the far west, was the impulse given to the effort, which has extended to all industries, to so improve all mechanical devices that manual labor would be minimized. In this region where only the search for wealth, sudden wealth, was the inspiring motive of the population, each man was his own employer to a large degree. In consequence labor was scarce and high priced. Necessity is ever the mother of invention, and the great want of the region, a full supply of labor, together with a thirst for wealth, pressed hard as incentives to obtain a substitute for the one and also to secure the other, by labor saving devices. No wonder that the search was active, was incessant, in all directions. No wonder largeness of operations captivated the venturesome in search of wealth, when the every day familiar object lesson of hydraulic mining taught that ample profits depended quite as much, if not more, upon the magnitude of the work than upon the richness of the material subjected to the work. Into this whirl of the mining fever men of all kinds of occupations had been drawn. Of the conventional, traditional miner there were not enough of them to go round in the places to be filled by skill. It was a free for all in the race for wealth, in which the mechanic, the tradesman, the farmer, men of all trades and professions, took a hand at mining. Throughout this multitude of workers there was an almost utter ignorance of the ruts of the profession or art of mining as taught in the foreign schools, the only schools, so that each started out with fresh ideas for the work in hand and worked along new lines. The continued friction of so much fresh, energetic thought, in no great time brought about almost a revolution in all mining work, as well as in its implements and accessories.

The steam hammer suggested the steam stamp to Wilson and Ball and they were quickly adopted in the Lake Superior copper region.

By skillful improvements they have been increased in efficiency until from a few tons per day they are now capable of crushing several hundred tons per day in regular work in that length of time.

The machine drill was another offspring of the steam hammer. Its great assistance to the miner has quite revolutionized his work. The Blake crusher, originally devised for crushing rock to make New England Macadam roads, was quickly seized upon by the gold miners, as a *sine qua non,* for their mills. At the hard iron ore mines of the Lake Superior region, since the soft ore miners are having their innings with the furnace men, Blake crushers of enormous size have been installed, in order to reduce the hard iron ore to small pieces so that it may be as acceptable to the furnacemen as the soft ores.

It would be an interesting recital to recount to you a small portion of the many achievements of American ingenuity in the field of mining, but your patience would be taxed to hear me through. Suffice it to say that no department of mechanics or scientific knowledge but has been ransacked by the eager miner to aid him in his undertakings. Confronted continually by new problems he has been ever athirst for knowledge which would give him the power to solve them. His spirit has been infectious. It has spread itself abroad into all the industrial activities.

There naturally resulted from this thirst for scientific, mechanical and technical knowledge an irresistable demand upon the old easy going, moss burdened colleges for schemes of study, such as were to be obtained abroad—schemes of study that touched the practical, the business side of life. One by one the old institutions of learning responded to this demand, establishing scientific, mechanical and technical departments and constituting them separate schools. States and public spirited private citizens have likewise yielded to this same impulse and have established and endowed other such schools. These citadels of a new education have attained to such strength, by the ability of their corps of instructors, by their magnificent equipments and by the generous support accorded them, that the incentives to the youth of our land to seek the instruction and advantages of foreign schools are greatly diminished. Already notable results are seen to flow from the stream of this new education and what may we not expect of its influence upon all that concerns our daily life when age shall have ripened its efforts.

Within this half century period just closing the known history of mining in the Lake Superior regions is compassed. Until the copper mines within its area were opened, success anywhere in the country by deep mining for ores of the metals was almost unknown.

Skillful mining was necessary to success, and to aid in this there was an influx of Cornish miners who helped largely to accomplish this, where the mines were well-located and well managed. With the iron mines of the region, however, success failed the investors until transportation, economic legislation and the demands of our Civil War, all together, operated in their behalf.

From that date with little variation the copper and iron mines have poured forth of their abundance to the astonishment of the commercial world. An enumeration of the Lake Superior product in iron ore and copper by five year periods beginning in 1854 exhibits the marvelous growth of these industries. A choice of a five year period is made, since it eliminates the annual ebb and flow of product due to varying market demand.

	Iron in Tons of 2,240 Lbs.	Copper in Tons of 2,000 Lbs.
1854-'59	59,941	18,360
1859-'64	559,566	31,539
1864-'69	1,713,756	39,625
1869-'74	4,456,375	66,732
1874-'79	4,927,123	89,456
1879-'84	10,909,699	131,646
1884-'89	18,373,485	192,171
1889-'94	38,486,626	261,720

Such figures not only attest the unbounded mineral wealth of this region, but the marvellous growth of our country in the mining of its two principal metalliferous ores. It would be a remarkable exhibit for our nation were these alone its total products. Statistics, however, show that the states outside of Michigan are large producers of copper and iron ore. These states in 1892 put forth an amount of copper more than double the copper product of Michigan. Statistics also credit the iron ore industry of the southern states in two decades with a product which shows a very great increase. Their product in 1870 was 346,513 tons, which increased to 624,164 tons in 1880, and in 1890 they attained to 2,890,997 tons. It is evident, therefore, that the abnormal stimulation of the mines of the Lake Superior district has not been made at the expense of a diminishing product of the same ores in other sections. Both the Lake Superior iron ore and copper production have been favored in quite recent years by new and undreamed of allies.

To our iron ore districts the Bessemer and other steel making processes have come with ever increasing demands for the better grades of ore. Year by year these processes yield the metal at lower and lower cost by reason of increased skill in manipulation and in consequence of greater magnitude of operations. By cheapening thus the cost the field of application of steel must without doubt widen and extend to a degree which it is beyond any one's ability to forecast. Of course it is to be admitted that a large part of the Lake Superior ores are not suitable for the acid Bessemer steel or open hearth processes, but the enlarged use of steel has helped to increase in due proportion the use of metal made from non-Bessemer ores. In electricity copper has an ally of greater possibilities even than the steel making processes have been in stimulating demand for Lake Superior iron ores. If one cannot foretell the possible expansion of the demand for our iron ore as influenced by the enlarged uses of steel, much less can one conceive the possible demands which the needs of electricity will make upon the producers of Lake Superior copper.

In the half century just being completed our Lake Superior region has grown from the obscurity of a wilderness to become the richest and foremost of the permanent mining regions.

The mine undertakings throughout the country at the beginning of the period exhibited and involved very little of skill and but insignificant capital. Since then mining enterprises have come to demand the highest skill. Many have grown to an extraordinary magnitude, requiring vast capital with commensurate ability in their mining and business departments to carry them along successfully. Where in the earlier times the miner had his few simple tools, his inefficient powder and meager facilities for doing his work economically, the miner of today is equipped with compressed air, machine drills, highly perfected explosives, electricity in its innumerable applications and all the labor saving facilities and enginery which skill can devise or money procure. No mining region has been more alert than this of the Upper Peninsula to secure whatever was procurable to aid in a cheapening of the cost of its product, and the competition of new mining fields has helped continually to emphasize the efforts of its miners to accomplish greater economies. In this direction our Institute can be helpful to the interests it represents. The mining of copper rock like the mining of iron ore is on a scale of great magnitude. What one of our members has accomplished at his mine in this district will avail us in the iron region and we hope *vice versa.* Free interchange of opinion and free inspection of each others' devices will awaken search along this and that line of economical work which, if left undiscussed and unobserved by others will leave each in his rut and no great progress ensue.

When the history of the progress of the region in mining art for the succeeding twenty-five or fifty years, as the case may be, shall have been written, our Institute, if it has been true to its opportunities, will be accounted one of the considerable factors which have contributed to the advances in mining that have been made.

ETCHED TUBES
SHOWING DIPS

CURVATURE OF DIAMOND DRILL HOLES.

BY J. PARKE CHANNING.

In the winter of 1892–3 I was doing some exploring on one of the Michigan Iron Ranges in which the ore formation was so deeply covered with drift of a wet and sandy nature that test pitting was out of the question.

On the hanging wall side was quartzite, and as the formation stood nearly upright it was determined to sink at various intervals sand shafts to this quartzite, about 250 feet beyond the line of contact of the quartzite and the formation; and then, by a series of fan holes, test this formation. From the first pit that we ledged at some 30 feet and sunk in the ledge 17 feet we drilled nine holes, testing the formation for a length of over 500 feet and to a considerable depth.

Knowing the strike of the formation and its approximate dip, I was considerably surprised, when drilling hole No. 3, to find that the stratification of the quartzite cores did not agree with the supposed strike, dip and angle of the hole.

One of them must have changed, and I was loth to believe that there could be an overturn.

Concluding that the hole must have changed its angle, I determined to test it, and knowing that hydrofluoric acid had been used for that purpose, I procured a bottle of a 20 per cent. solution of that acid, and getting some pieces of ⅞″ combustion tubing, made some test tubes 5″ long. In one of these I poured 2″ of the hydrofluoric acid, put in a rubber cork, and having blocked the bit with a plug of wood, I introduced the corked tube in the core shell, screwed the core shell on the core barrel and lowered the rods to the bottom of the hole.

This hole had been started at an angle of 45° and was then down 531′ 6″. The time occupied in lowering was 30 minutes. The rods were left in the hole 90 minutes and it took 45 minutes to pull the rods out. The hydraulic pressure at the bottom of the hole had forced the rubber cork down in the tube, compressing the air, and inside was a very mixed up mess of a milky liquid.

Examination showed, however, a well defined elliptical ring of adherent crystals which, when holding the tube in the proper position, coincided with the water level. This ring was not, however, continuous, because of the cork having been forced down so deep in the tube.

Laying the tube on one edge of a geological clinometer and tilting the clinometer and tube till the water and crystal line were coincident, 30° was easily read, showing that the hole had flattened 15° in the 531.5 feet.

I was so encouraged by the results of this test that I sent to Eimer & Amend and had made a dozen special tubes 1″ in diameter, 5″ long, with ground glass stoppers, such as I show you.

Hole No. 4 was now down 175 feet, having been started at an angle of 45°. I sent down one of the new tubes, having taken the precaution to drive a wooden plug in the core barrel so that the water in the rods would not have a tendency to force the tube out while pulling up. We lowered in 15 minutes, left the rods down two hours, pulled up, and found the tube filled with liquid, whereas I had only put in about 2″ of mixed acid and water. The hydraulic pressure had worked in through the ground glass joint and diluted and filled the tube, and we had no test.

I tried it again, this time blocking the core barrel and the bit each with a dry wooden plug, and making small gaskets for the joints between the bit, the shell and the barrel. I had the same results, however, the water had worked its way through the fibers of the wooden plugs and my test was again spoiled. After trying a couple of the old style rubber combustion tubes and getting only fair results, I took one of the special tubes and, before putting in the acid, heated it and at the same time dipped the stopper in melted paraffine. The acid was then put in, the stopper with its film of melted parafine quickly pressed in and the tube inserted in the core shell. This tube gave me the first clear and distinct test. It showed 35° at a depth of 175 feet.

From that time on the use of the tube became very simple. I found that ample time could be taken to pour in the acid, affix the stopper and insert the apparatus in the core shell. My foreman had no difficulty in making the tests.

The final method of work was as follows: A blank tube was put in the combined bit and core shell from the top end until the lower end rested on the spring. Holding this in position it was laid beside the core barrel so that the length of thread was allowed for, and a file mark made on the core barrel just even with the top of the glass stopper. A dry wooden plug was made to fit the core barrel and driven in till it just cleared a point corresponding to the file mark. The core barrel was now clamped in a vise in a nearly vertical position.

The stopper of the tube was held in a tin spoon with a little paraffine over a candle flame and the upper end of the tube warmed. An inch of 20 per cent hydrofluoric acid was carefully poured in the tube, then an inch of water and the stopper taken from the melted spoon of wax, smartly wrapped to throw off any excess of paraffine and quickly put in the tube. The acid immediately heated up the tube but no ill effects were felt from this. Wrapping a thread or two of lamp wicking around the neck of the tube, it was put in the core shell and still holding it in an upright position the upper end was introduced into the core barrel and the thread between the shell and the barrel screwed up. Carrying the barrel in an upright position it was put down the hole and no special pains taken in lowering down the rods, save to touch the bottom of the hole carefully.

I made several experiments in regard to the time necessary to leave the tube in the hole, and found that two hours was as good as twenty-four. One hour did not give very good results.

The churning up that the acid had in going down the hole did not in the least affect the test, and the results were generally as clear as these I show you.

When the tube came out of the hole I generally tried it before taking the stopper out, making the liquid coincide with the line of crystals. Then I removed the stopper, cleaned out the crystals, and putting in fresh water tried the angle again, using for a guide that portion of the glass which had been etched by the acid.

The hydrofluoric acid dissolved the $Si\ O_2$ of the glass, producing the fern like form on it, and finally, as the solution cooled off, deposited the line of crystals around the top.

Below I give you a table of the dips of the holes at the various points at which I made observation.

Hole No. 1—	Hole No. 2—	Hole No. 3—
Collar 15°	Collar 30°	Collar 45°
275 ft. 3½°	200 ft. 13°	531.5 ft. 30°
	397 ft. 9½°	
Hole No. 4—	Hole No. 5—	Hole No. 6—
Collar 45°	Collar 45°	Collar 45°
175 ft. 35°	100 ft. 33°	208 ft. 31°
353.6 ft. 3°	175 ft. 22°	416 ft. 10½°
	252.5 ft. 11°	
	330 ft. 3°	
Hole No. 7—	Hole No. 8—	Hole No. 9—
Collar 60°	Collar 39°	Collar 45°
100 ft. 57½°	100 ft. 32°	375.7 ft. 30°
200 ft. 51°	200 ft. 19°	
300 ft. 41°	300 ft. 9°	
400 ft. 30°	407.3 ft. 6½°	
576 ft. 18°		

In order to see if the rods would really turn when bent at angles as shown by the above record, I connected together 50 feet of Sullivan E rods whose external diameter is 1.1315 inches, being made of double thick pipe. Curving this so that the depth of the arc was six feet, I had no difficulty in "tonging"

the rods with a pipe wrench. This curvature was much greater than that found in the holes.

Having satisfied myself that the holes did curve as is shown in the diagram, I replatted all the holes and redetermined the latitudes and departures and depths of where the holes left the quartzite and entered the ore formation. This second plat more nearly agreed with the actual condition and reduced chaos to something like order.

There is one point, however, which I failed to determine, and that is the amount of lateral deviation of the holes, if any. If the county I had been working in had been totally free from local attraction, there would have been no difficulty in sending down in the core shell a small compass mounted on a universal bearing with a tripping arrangement to set it when the bottom of the hole was reached and the needle quiet. As it is, I am left in the dark on that point. I have strong reasons for believing that hole No. 3 veered around to the left, as its horizontal projection without that assumption throws the contact plane into the hanging.

Anybody who can solve that problem will place in the hands of the driller information which, with such as I have indicated, will tell him nearly where the point of his hole is.

As will be seen from the records, after we got started the dip of the hole was tested every 100 feet, and thus we kept a fair idea of where we were. On some of the deep holes the point was 50 feet higher up and 50 feet farther away from the collar of the hole than if it had gone straight.

In looking about to discover why the holes flattened, I remembered that about the last part of hole number two we put in a new core barrel. These core barrels when new are 1½″ diameter, but after use wear down to 1¼″ at the upper end. The bits I used were 1 17-32″, and the clearance of the stone 1-64″ on each side, so that the gauge of a new bit was 1 17-32 + 2-64 = 1 9-16. It is quite evident that with an old core barrel 1 1-4″ diameter at its upper end and a bit 1 9-16″ at its lower end, and this bit constantly kept up to gauge, that we have a 10 foot tapered boring tool. The weight of the rods and their pressure produce a tendency for the upper end of this tool to rest on the bottom of the hole, and thus in a distance of ten feet we have the line of tool 5-32″ out from the line of the hole in which the tool rests.

With this in view, it seems quite evident that the new core barrel kept the latter part of hole number two fairly straight. The core barrel was not badly worn, hence hole number three only flattened 15°. By about the time hole number four was half through the barrel got very thin, and away went the hole on its flat course. No. 5 and No. 6 curved pretty well, but as they cut the formation quicker nothing was done to prevent it.

In hole No. 7 I had a particular point in the formation to strike and tried to keep the hole from flattening excessively. I think I was not very successful. In attempting this I had a special coupling made to go between the rods and the core barrel. It had a six inch bearing on it and was the size of a blank bit, 1 17-32″ This was made of steel and tempered. It soon wore down giving away farther on one side than the other, and a second one went in the same manner. I still think that a case-hardened coupling or one in which a great many carbon chips were set, might enable one to drill a comparatively straight inclined hole.

About this time I had on another property near Amasa, Mich., a test pit or rather small shaft that was 143 feet deep. We had three No. 8 pumps in it when at the above depth we struck more water. A steel bar showed it to be 17 feet more to ledge and pretty bad sand to go through. Knowing that the formation was on the side of the shaft, I concluded to sink an angle stand pipe from the bottom of this pit. This pipe I got down at an angle of 60° after driving 25 feet of pipe, but as Kipling says, "That's another story."

As I wanted to cut the formation as quickly as possible, I had no relish for continuing at 60° and so made preparations for flattening the hole. I used an old worn 5 ft. core barrel, blank bits 1 5-8″ and stones with all the clearance they would stand. At 121 feet from the collar the hole had flattened to

52°, at 196 feet it had got down to 44°. The two tubes I show you are the tests at those points.

About this time I left the work in charge of Mr. Roscoe H. Channing, Jr., and as he is unable to be present at the meeting I will ask him to give the final figures in the written discussion.

Hole number nine at the first pit mentioned was also drilled by Mr. R. H. Channing, and I believe he succeeded in keeping it so straight by using 1½″ blank bits with but little clearance and a new core barrel.

The work of the nine fan holes was done with an "S" drill of the Sullivan Machinery Co., and the hole near Amasa by an "E" drill of the same make. Although somewhat foreign to the subject, I give the cost of drilling the first 2,091 feet at the fan hole pit.

This cost includes everything, from the time the pit was left in shape for the drill to go down.

Labor on drills	$606
Firemen	206
Fuel	182
Camp account	722
Repairs on drills, bits, core barrels, etc.	126
Repairs on boilers and machinery and sundry supplies	97
Carbons	239
Superintendence	196
	$2,374

This includes running a No. 7 pump to keep the water out.

DISCUSSION.

Mr. Denton—"I would like to ask Mr. Channing if an attempt was made to get at the direction of the deflection of any of the holes by drawing the rods slowly?"

MR. CHANNING—"No, there was not. We discussed the practicability of drawing them so that they would not be twisted in that process, but I found that there was so much spring in the rods that there was no difficulty in giving the top a complete turn before the bottom would start to move. It seemed evident that the rods would twist more or less, no matter how carefully handled."

MR. WINCHELL—"I would like to ask, Mr. President, if there was anything in the structure of the rock through which the drill passed that would make the drill pass up rather than down?"

MR. CHANNING—"I think not. The ground through which the drill passed was a comparatively homogeneous quartzite of a fragmental nature. In places it was schistose, but still homogeneous. At Amasa the hole did not flatten as much or as rapidly as I wished. The ground there was soft slate, and the weight of the rods and the pressure behind them tended to increase the rate of drilling and not to increase the bending of the rods, as in the harder material."

MR. WINCHELL—"Would the rods always turn so as to conform more nearly with the stratification?"

MR. CHANNING—"I have heard that claim made and also the opposite, that the holes tended to take a course at right angles to the formation. In my case the latter seemed more near the truth."

MR. BURT—"I should like to ask Mr. Channing whether he is familiar with, or recollects, the hole we drilled at the Ironton, now the Lowell, at the time he was mine inspector?"

MR. CHANNING—"Yes; I remember the hole. It was started at the bottom of the shaft and in line with it, and given a dip some 10° flatter than the formation. This shaft was on the quartzite footwall. At about 102 feet the bit, after running through clean ore most of the way, was lost, and although I understand it was eventually found, I do not know in what position."

MR. BURT—"Some time after you left, the shaft was sunk, the ore dug out, and the bit, which according to the original course should have been forty feet north of the footwall, was found imbedded close to the footwall and about fifteen feet west of the shaft."

MR. CHANNING—"I can quite understand Mr. Burt's case. There he was drilling in soft ore, and I have no doubt that the ore ground up and washed away on all sides. Of course the bit, core barrel and all would follow the line of least resistance in the bottom of the large hole."

MR. KELLY—"Having talked a little with Mr. Channing about his experience in drilling holes, I thought I would try to get some idea as to the flexibility of the diamond drill rod, and so I got out two hundred feet and proposed to raise up both ends to see what the flexibility was. We raised one end against a shaft house about fifty feet high, and then raised the other end about thirty-five feet, but we could not lift the center off the ground, and I came to the conclusion that the diamond drill rod was very much like a rope."

MR. POPE—"I would like to inquire, if in drilling a hole at an angle and below the horizon the tendency is for the drill and bit to raise, why it would not do so in a horizontal hole, or why it should run straighter on the horizontal than at an angle?"

Mr. PASCOE—"I have heard that question a great many times. I have drilled several thousand feet and found that the horizontal holes invariably raised as they gained in length. In drilling flat holes, in nine cases out of ten the hole rose as it went ahead. The holes were started three feet from the bottom of the level, and were drilled to find if the lenses of ore that were in the levels above had continued in depth. If the hole discovered the ore then we drifted on it keeping the hole in the drift as long as we could, but if the drift was of any great length, the diamond drill hole raised above the back of the level in every case."

MR. PARKER—"How was the stratification? Were the holes laid out with the stratification or square against it?"

MR. PASCOE—"The stratification at the Republic mine changes in both direction and dip, as it bends around 'Smith's Bay,' and is very much broken and distorted in some places. In the southern and western parts the lenses of ore are formed across the strata lines. In drilling those holes, sometimes they were with the strata, sometimes square across it and sometimes oblique, but the holes were drilled in every direction regardless of the stratification, and almost every hole showed a tendency to raise."

HISTORICAL SKETCH OF THE DISCOVERY OF MINERAL DEPOSITS IN THE LAKE SUPERIOR REGION.

BY HORACE V. WINCHELL.

The development of mining industry in the territory about us is so recent that its very beginning lies within the recollection of many. The earliest statistics of production commence but half a century ago, and yet how wonderful the growth and how fabulous its story! It might appear at first sight unnecessary to detail the early history of so young an industry in so new a region. But most of us are new comers here, and have taken things as we found them, without a careful investigation into the beginning of it all. We are well aware of the fact that we are in the midst of a district of marvelous natural resources. We know full well that in addition to our natural advantages American inventive skill and indomitable enterprise have pushed developments until our iron and copper mines are the wonder of the civilized world, and knowing these things we may have overlooked the day of small beginnings, and forgotten to inquire to whom we owe our present fame and wealth. It therefore seems appropriate that a brief summary of the order and date of early events should be presented before this Institute. Some of our traditions may not have a basis of fact, and others may have become more or less intermingled with fiction. It shall be our endeavor to collect the scattered data and present a narrative which shall render honor to whom honor is due for the discovery of our mineral wealth.

PREHISTORIC MINING.

Although the exploitation of our mines on a commercial scale has been in progress less than two generations, we cannot pride ourselves on being the original discoverers and users of the metals they produce. I shall make quotations from the several writers on the subject, during the reading of this paper, without giving exact reference in each case. The bibliographical list appended hereto will furnish information as to the place where the reports quoted appeared. As to the use of metals by the Indians, Jackson remarks:

Long anterior to the settlement of this country by white men the children of the forest were familiar with the use of native metals, such as gold, silver, copper, and perhaps meteoric iron. Their wandering mode of life prevented the cultivation of the metallurgic art, and it is not supposed that they knew how to reduce metals from their ores by the forge or furnace. There is reason to believe that the aborigines in some parts of the country understood the art of obtaining metallic lead from the sulphuret, for the metal is so easily reduced from that ore by roasting it on an ordinary log fire, that it seems impossible for them to have failed to obtain lead if they even threw pieces of the ore into a fire. In the western states, where the lead ores occur loose in the soil and in decayed seams of the rocks, the Indians would have been most likely to have discovered the art of sme'ting lead. That metal is probably the only one they knew how to extract from its ores; but they understood the art of annealing the native metals by means of fire, and we find proofs in the ancient workings on Lake Superior, as well as in the accounts recorded by the ancient French Jesuits, who were the first Europeans that visited the lake, that the Indians built fires on and around the masses of native copper which were too large to be removed, and after softening the metal, cut off portions with their hatchets. They understood how to fashion the malleable native metals into all the various weapons, ornaments or tools employed by them, and manifested considerable ingenuity and skill in this handicraft, but no proofs have ever been discovered that they ever made any castings of metals fusible at a high temperature. Throughout the continent, wherever gold, silver or copper is found native in the soil, or in the decayed rocks, the aboriginal inhabitants were accustomed to work these metals into various articles, by hammering them with smooth stones, affixed to a withe bound round in a groove cut in the middle of the stone. (Loc. cit. p. 373.)

But these "first families of America" went farther than the use of metals found in the glacial drift. They engaged in the operations of mining, in a manner similar to that revealed in the earliest mines of Great Britain, and with equally crude implements. Of some of these prehistoric mines Whittlesey speaks as follows:

The evidences of ancient mining operations within the mineral region of Lake Superior were first brought to public notice in the winter of

1847–8. Although the Jesuit fathers frequently mention the existence of copper, and even use the term *mines*, it is clear, from the general tenor of their narratives, that they neither saw nor knew of any actual *mining* in the technical sense of that word. They announced as early as the year 1636 the presence of native copper, and refer to it as having been taken from the "mines." This was prior to the time when they had themselves visited the Great Lake, and their information was derived from Indians. At the same time they speak with equal certainty of mines of gold, *rubies and steel;* but it must be borne in remembrance that the French word is not equivalent to our English *mines*, but may be more correctly rendered veins or deposits of metals or ores.

In the "Relacions" for 1859–60 after missions had been established on Lake Superior, the region is reported to be "enriched in all its borders by mines of lead almost pure and of copper all refined in pieces as large as the fist, and of great rocks which have whole veins of turquoise!" It is probable that these accounts are second-hand, and such as the Chippewas gave when they exhibited to the fathers specimens of native metal in the shape of water-worn pieces and small boulders.

Boucher, in the "Histoire veritable," etc., in 1640, asserts that "there are in this region, mines of copper, tin, antimony and lead." He speaks of a great island fifty leagues in circumference, which is doubtless the one now called Michipicoten, where "there is a very beautiful mine of copper." Copper was also found in other places in large masses "all refined;" in one instance an ingot of copper was discovered which weighed more than 800 pounds, and from which the Indians cut off pieces with their axes after having softened it by fire. All this information Boucher obtained from some French traders, and not from his own observation.

The discovery of the first ancient mine is credited to Mr. Samuel O. Knapp, the agent of the Minnesota Mining Company. It was in the winter of 1847-48, at the Minnesota Copper mine, and the discovery is thus related by Foster and Whitney:

In passing over a portion of the location now [1850] occupied by the Minnesota Mining Co., he observed a continuous depression in the soil, which he rightly conjectured was caused by the disintegration of a vein. There was a bed of snow on the ground three feet in depth, but it had been so little disturbed by the wind that it conformed to the inequalities of the surface. Following up these indications along the southern escarpment of the hill, where the company's works are now erected, he came to a longitudinal cavern, into which he crept, after having dispossessed several porcupines which had selected it as a place of hibernation. He saw numerous evidences to convince him that this was an artificial excavation, and at a subsequent day, with the assistance of two or three men, proceeded to explore it. In clearing out the rubbish they found numerous stone hammers, showing plainly that they were the mining implements of a rude race. At the bottom of the excavation they found a vein with ragged projections of copper, which the ancient miners had not detached. This point is east of the present works.

The following spring he explored some of the excavations to the west, where one of the shafts of the mine is now sunk. The depression was twenty-six feet deep, filled with clay and a matted mass of mouldering vegetable matter. When he had penetrated to the depth of eighteen feet, he came to a mass of native copper ten feet long, three feet wide, and nearly two feet thick, and weighing over six tons. On digging around it the mass was found to rest on billets of oak, supported by sleepers of the same material. This wood, specimens of which we have preserved, by its long exposure to moisture, is dark-colored, and has lost all its consistency. A knife-blade may be thrust into it as easily as into a peat-bog. The earth was so packed around the copper as to give it a firm support. The ancient miners had evidently raised it about five feet and then abandoned the work as too laborious. They had taken off every projecting point which was accessible, so that the exposed surface was smooth. Below this the vein was subsequently found filled with a sheet of copper five feet thick, and of an undetermined extent vertically and longitudinally.

No less than ten cart loads of stone hammers, both with and without grooves, were found in this vicinity, besides a variety of other mining tools, among which may be mentioned cedar gutters or troughs to drain off the water, which was baled up in wooden bowls, cedar shovels, copper wedges or gads, copper chisels and spear heads, ladders formed of oak trees with the branches left projecting, wooden levers, copper mauls, etc.

There were three principal groups of these ancient diggings on Keweenaw Point, viz.: One a little below the forks of the Ontonagon river, another at Portage lake, and a third on the waters of Eagle river. Although the old works were not always situated on good veins, yet they were regarded by practical miners as good guides to the valuable lodes. There were other veins on Isle Royale and near the north shore, opposite Keweenaw Point, which were extensively wrought in olden times. Whittlesey also states that in the other direction, "sixty and eighty miles to the southeast, in the iron region near Marquette are remains that are also ancient."

The date when these mines were worked and the races that wrought them are unknown. It is generally believed that the tools and implements found there are relics of the Mound Builders, and the opinion is gaining ground that the Mound Builders were ancestors of our present Indians. The discovery of two hemlock trees on which were counted 290 and 395 rings respectively, growing on the rubbish heaps of these old workings, and the further observations made by Whittlesey, showing that there were decayed trunks of trees of the same species but of a still earlier generation lying in these troughs, are evidence that the works must have been abandoned 200 or 300 years before Columbus started on his voyage of discovery. The further fact that their existence was unknown to the Indians at the earliest time of which we have any record, is another proof of their great antiquity.

It does not appear that the natives mined silver or gold as they did copper. It is not unlikely that they were familiar with the metals, and were aware of their occurrence in the drift, mingled with the copper, or in the rocks of Thunder Bay. But since they do not occur in large masses like copper, and the Indians had no idea of fusing or smelting them into ingots, but little use was probably made of them.

EARLIEST DISCOVERIES BY WHITE PEOPLE.

The first white man to visit Lake Superior was Jean Nicollet*, who was sent from Quebec by Champlain, with seven Huron Indians as his only companions, on July 1, 1634. He did not come so far west as the copper district, however, but went back through the Straits of Mackinaw down to Lake Michigan, after staying some time for rest at the place since called Sault Ste Marie. It was not until 1666-67, about the time that Marquette established the Mission at Sault Sainte Marie, that we have more detailed accounts than those furnished by Lagarde in 1636 and the relation already mentioned.

*H. V. Winchell, *American Geologist*, Feb., 1894, p. 126.

In the relation of Claude Allouez (1666–67), there is a chapter entitled, "Mines of Copper which are Found on Lake Superior," from which is taken the following (Jackson's Lake Superior, p. 378):

Up to the present time it was believed that these mines were found on only one or two of the islands; but since we have made a more careful inquiry, we have learned from the savages some secrets which they were unwilling to reveal. It was necessary to use much address in order to draw out of them this knowledge, and to discriminate between the truth and falsehood. We will not warrant, however, all we learned from their simple statements, since we shall be able to speak with more certainty when we have visited the places themselves, which we count on during this summer, when we shall go to find the "wandering sheep" in all quarters of this great lake. The first place where copper occurs in abundance after going above the Sault is on an island about forty or fifty leagues therefrom, near the north shore, opposite a place called Missipiconatong.

The savages say it is a floating island, which is sometimes far off and sometimes near, according as the winds move it, driving it sometimes one way and sometimes another. They add that, a long time ago, four Indians accidentally went there, being lost in a fog, with which this island is almost always surrounded. It was long before they had any trade with the French, and they had no kettles or hatchets. Wishing to cook some food, they made use of their usual method, taking stones which they picked up on the shore, heating them in the fire, and throwing them into a bark trough full of water in order to make it boil, and by this operation cook their meat. As they took up the stones they found they were nearly all of them pure copper. * * * Before leaving they collected a quantity of these stones, both large and small ones, and even some sheets of copper; but they had not gone far from the shore before a loud voice was heard, saying in anger, "Who are these robbers who have stolen the cradles and playthings of my children?" The sheets of copper were the cradles, for the Indians make them of one or two pieces of wood (a flat piece of bark with a hoop over one end), the child being swathed and bound upon the flat piece. The little pieces of copper which they took were the playthings, such pebbles being used by Indian children for a like purpose This voice greatly alarmed them, not knowing what it could be. One said to the others it is thunder, because there are frequent storms there; others said, it is a certain genii whom they call Missibizi [Mesabi], who is reputed among these people to be the god of the waters, as Neptune was among the pagans; others said that it came from Memogovisiousis —that is to say, sea-men, similar to the fabulous Tritons, or to the Sirens, which live always in the water, with their long hair reaching to their waists. One of our savages said he had seen one in the water;

nevertheless, he must have merely imagined that he did. However, this voice so terrified them that one of these four *voyageurs* died before they reached land. Shortly after, a second one of them expired; then a third; so that only one of them remained, who returning home told all that had taken place, and died shortly afterwards. The timid and superstitious savages have never since dared to go there for fear of losing their lives. * * *

Advancing to a place called the Grand Anse (Great Bay), we meet with an island three leagues from land, which is celebrated for the metal which is found there and for the thunder which takes place, because they say it always thunders there (Thunder Cape). But further towards the west, on the same north shore, is the island most famous for copper, called Minong (the good place), Isle Royale. This island is twenty-five leagues in length; it is seven leagues from the main land and sixty from the head of the lake. Nearly all around the island, on the water's edge, pieces of copper are found, mixed with pebbles, but especially on the side which is opposite the south, and principally in a certain bay which is near the northeast exposure to the great lake. There are shores "tous escarpéz de terre glaize," and there are seen several layers or beds of copper, one over the other, separated or divided by other beds of earth or rocks. In the water is seen copper sand, and one can take up in spoons grains of the metal big as an acorn, and others fine as sand. (This description probably refers to Rock Harbor). * * Advancing to the head of the lake and returning one day's journey by the south coast, there is seen in the edge of the water a rock of copper which weighs 700 or 800 pounds, and is so hard that steel can hardly cut it; but when it is heated it cuts as easily as lead. Near Point Chagaouamigon, where a mission was established, rocks of copper and plates of the same metal were found on the shores of the islands.

Last spring we bought of the savages a sheet of pure copper, two feet square, which weighed more than 100 pounds. We do not believe, however, that the mines are found on these islands, but that the copper was probably brought from Minong (Isle Royale), or from other islands, by floating ice, or over the bottom of the lake by the impetuous winds, which are very violent, particularly when they come from the northeast.

Returning still towards the mouth of the lake, following the coast on the south, at twenty leagues from the place last mentioned, we enter the river called Nantounagan (Ontonagon), on which is seen an eminence where stones and copper fall into the water, or upon the earth; they are readily found. * * *

Proceeding still further, we come to the long point of land which we have compared to the arrow of the bow (Keweenaw point); at the extremity of this there is said to be a small island which is said to be only six feet square, and all copper! * * We are assured that copper is found in various places along the southern shore of the lake.

In the "Relations" for 1670-71, Pere d' Ablon remarks that

"The great rock of copper of 700 or 800 pounds, and which all the travelers saw near the head of the lake, besides a quantity of pieces which are found near the shores in various places, seem not to permit us to doubt that there are somewhere the parent mines, which have not been discovered."

Baron la Hontan refers to mines of pure copper on Lake Superior in his "Voyages dans l'Amerique septentrionale," published in 1688.

In the "Histoire de la Nouvelle France," by Peter Francois Xavier Charlevoix (Tom. IV, p. 415) is another account of native copper. This Jesuit made a "tour of the great lakes" in 1721, but does not appear to have visited Lake Superior.

Peter Kalm, a Professor of "Oeconomie" in the University of Abo, in Swedish Finland, traveled in the provinces in 1748 and 1749. He also mentions having seen masses of copper which came from the "Upper Lake," and were brought down by the Indians. He speaks of them as being found in the ground near the mouths of rivers and supposes that ice or water carried them down the sides of mountains. (London Ed., vol. 3. p. 278.)

The first attempt at mining appears to have been made by Alexander Henry, an Englishman who came to North America soon after the conquest of Canada by the British. He is said to have been attracted by the accounts given by Carver in 1765; but this does not appear to be the case, since he was here about the same time. He was saved at the massacre of Fort Mackinaw by an Indian, who adopted him and concealed him in a cave on Mackinaw Island. During the years 1765–1770 he was occupied in coasting around the shores of Lake Superior looking for mineral treasure. In his "Travels," published in New York in 1809, he mentions the mass of copper near the mouth of the Ontonagon river which was afterwards removed to Washington, and states that he cut off from it with his axe a portion weighing a hundred pounds. He passed the winter of 1767 at Michipicoten on the north shore, near which point he discovered numerous pieces of "virgin copper" and a vein of lead ore. In 1770 he associated himself with Messrs.

Baxter and Bostwick in a "company of adventurers for working the mines of Lake Superior." They built a barge at Point aux Pins, and laid the keel of a sloop of forty tons. Early in May, 1771, they sailed for the island of yellow sand, where they expected to find gold, and make their fortunes; but they found nothing of value. The miners examined the coast of Nanibojou, and found several veins of copper and lead, after which they returned to Point aux Pins, and erected an air furnace. "The assayer reported on the ores which they had collected, stating that the lead ore contained silver in the proportion of forty ounces to a ton; but the copper ore only a very small proportion indeed."

From Point aux Pins they crossed over to Point aux Iroquois, where Mr. Norberg, a Russian gentleman, acquainted with metals, and holding a commission in the 60th regiment, and then in garrison at Michilimackinac, accompanied them on this latter expedition. Mr. Norberg found a loose stone weighing eight pounds, of a blue color and semi-transparent. This he carried to England, where it produced in the proportion of 60 pounds of silver to a hundred weight of ore. It was deposited in the British Museum. Henry now revisited the Ontonagon river, where, besides the detached masses of copper formerly mentioned, he saw "much of the same metal bedded in the stone." They built a house and sent to the Sault for provisions. He pitched upon a spot at the commencement of mining operations, and remarks that there was a "green-colored water which tinged iron of a copper color." * * * * * In digging they frequently found masses of copper, some of which were three pounds in weight.

On the 20th of June, 1772, the miners returned, after having passed the winter at the Ontonagon. Their drift had caved in during a thaw, and just as they supposed they were about to come upon a solid vein of copper, but in reality just on the solid red sandstone. Henry claims that it was not for copper, but for silver, that their company was formed, and that they expected to find it mixed with either the copper or the lead. In the summer of 1773 Henry and his crew worked in solid rock on the north shore, drifting into a vein which carried some copper, but which contracted from a width of four feet to as many inches in the distance of thirty feet. What ore they had was sent to England, but the English partners had had enough, and refused to contribute further to the expenses of the enterprise. Mr. Henry thus describes the termination of affairs: "This year, therefore (1774), Mr. Baxter disposed of the sloop and other effects of the company, and paid its debts. The partners in England were, his royal highness, the Duke of Gloucester, Mr. Secretary Townshend, Sir Samuel Tuchet, Mr. Baxter, Consul of the Empress of Russia, and Mr. Cruickshank. In America, Sir William Johnson, Mr. Bostwick, Mr. Baxter and myself. A charter had been petitioned for and obtained, but owing to our ill success it was never taken from the seal office."

COPPER MINES.

There does not appear to have been any mining in progress for nearly 70 years after the efforts made by Alexander Henry. Indeed, the occurrence of copper seems to have been almost forgotten, and was only casually mentioned. There were no explorations made of any sort, looking toward the development of mines, until Douglass Houghton was appointed State Geologist of Michigan in March, 1838: Even then, and although he must have been familiar with the facts concerning the distribution of drift copper, from his former explorations made in 1831 and 1832, yet nothing appears to have been done toward investigating the copper range until 1840. In his fourth annual report, submitted February 1, 1841, we find a discussion of the general prospects for profitable mining, including a description of the veins, and a comparison of them with those of Cornwall in which the statement is made (p. 58) that "After as minute an examination of the subject as circumstances will permit, I am led to the conclusion that the only ores of the metallic minerals, occurring in those portions of the veins, which traverse the rocks last alluded to, which can be reasonably hoped to be turned to practical account, are those of copper." He acknowledges that he was inclined to regard the occurrence of native copper as an unfavorable indication for permanence in mining until he had discovered that "that feature was more or less universal with respect to all the veins." He expresses himself in conclusion in the following conservative manner:

"While I am fully satisfied that the mineral district of our state will prove a source of eventual and steadily increasing wealth to our people, I cannot fail to have before me the fear that it may prove the ruin of hundreds of adventurers, who will visit it with expectations never to be realized. The true resources have as yet been but little examined or developed, and even under the most favorable circumstances we cannot expect to see this done, but by the most judicious and economical expenditure of capital, at those points where the prospects of success are the most favorable. * * * I would by no means desire to throw obstacles in the way of those who might wish to engage in the business of mining this ore, at such time as our government may see fit to permit it, but I would simply caution those persons who would engage in this business in the hope of accumulating wealth suddenly and without patient industry and capital, to look closely before the step is taken, which will most certainly end in disappointment and ruin."

In a letter written by Dr. Houghton to Hon. Augustus Porter, member of Congress from Detroit, replying to an inquiry in the "National Intelligencer," and dated December 26, 1840, we find substantial proof that he was not only acquainted with the location of some of the copper veins, but that he had actually gone into them and obtained native copper. His own statements are as follows (Bradish's "Memoir of Douglass Houghton," pp. 114-116).

Ores of zinc, lead, iron and manganese occur in the vicinity of the south shore of Lake Superior, but I doubt whether these, unless it be zinc and iron, are in sufficient abundance to prove of much importance. Ores of copper are much more abundant than either of those before mentioned, and a sufficient examination of them has been made to satisfy me that they may be made to yield an abundant supply of the metals. I do not mean by this that copper is to be found in that region. as is the popular opinion, pure and without labor, but that capital may be safely invested in raising and smelting of these ores with profit to the capitalist. * * * The veins of ore traversing the mineral district of Lake Superior, in those portions I have examined closely, are of very frequent occurrence, and range from a few inches to fourteen feet in width. I do not now recollect (I write without a reference to field notes) that I traced any of those veins over a mile in length, and most of them less. * * * I brought from Lake Superior on my return to Detroit this fall from four to five tons of copper ores and am now busily engaged in making an analysis of them. Thus far they have proved equal to any ores I have ever seen, and their value for purposes of reduction cannot be doubted. The average per cent of metal is considerably above that of the ores of Cornwall. While speaking of the ores I am reminded of the beautiful specimens of native copper which came out with the ores in opening some of these veins. They are not very abundant, but some of them are very fine. In opening a vein, with a single blast I threw out nearly two tons of ore, and with this were many masses of native copper, from the most minute specks to about forty pounds in weight, which was the largest mass I obtained from that vein. Ores of silver occasionally occur with the copper, and in opening one vein small specks of native silver were observed. There are as yet, however, no evidences of the existence of this metal in sufficient abundance to be of practical value. * * * I hope to see the day when instead of importing the whole of the immense amount of copper and brass used in our country we may become exporters of both.

Dr. Houghton did not mention in his annual reports the location of any of the veins which he discovered, with one exception, viz., that of the green silicate of copper at Copper Harbor. The land had not at that time been thrown open for settlement or even for exploration, and he was undoubtedly reserving the details for publication in his final report, which he did not live to complete, owing to his untimely death by drowning, in Lake Superior, during a snow storm and gale near Eagle river, on October 13, 1845.

His official report, however, called attention to the possibilities of the region; and the cession of the land to the United States by the Chippewas, which was ratified March 12, 1843, was the signal for the commencement of a speculative craze which lasted for three years, and completely justified the fears expressed by Dr. Houghton in anticipation.

Credit for first calling attention to the copper range in a general way and for recommending its development must thus be given to Douglass Houghton. To Charles T. Jackson, however, undoubtedly belongs further credit for personally examining at a very early date and approving or condemning many of the veins which were afterwards worked. We all know that the first mines were not in the conglomerate as at present, but in true fissure veins which crossed the conglomerate and interleaved amygdaloidal trap sheets in several systems. In these veins the copper (with a little silver) usually occurs native in masses of all sizes up to a thousand tons. The copper itself is 90 to 95 per cent. pure, and is believed to owe its origin to electro-chemical action which replaced portions of both the amygdaloid and conglomerate. In his report for 1849 Jackson distinctly states his claims for priority of discovery of the value of these veins. His first explorations were made in the summer of 1844, while in the employ of Hon. David Henshaw, who accompanied him to Keweenaw Point "for the purpose of examining the country for copper." The linear survey had not at that time reached any portion of the so-called mineral lands, and Keweenaw Point presented an unbroken wilderness. There was, however, already a crew of miners at work for the Lake Superior Mining Company (which thus seems to have been the first incorporated organization in the field) and an encampment of United States soldiers.

These facts are mentioned by Jackson (loc. cit. p. 386), who further states that, although up to that time no such phenomena as veins of native copper had been known to exist and it would even have been "hazardous to the reputation of any geologist, who was not prepared to demonstrate the fact, to declare his belief in the practicability of mining for *native copper;*" yet in his first surveys on Lake Superior (1844) he took "care to collect ample proofs of the existence not only of true veins of native copper, but also to prove the extent of the veins (as far as was possible by surface observations) and that they became richer as they descended into the rocks."

He then proceeds to give the history of the first operations as follows (pp. 386–387):

The only houses which had been erected were the office of government mineral agency of General Walter Cunningham, at Porter's Island, Copper Harbor, and a rude log hut, built by Charles Gratiot, Esq., at Eagle Harbor, for the accomodation of his party of explorers. Not a road or trail existed anywhere on the point, and the tangled growth of spruce and white cedar obstructed the banks of the streams and the coast, giving a most unpromising appearance to the country, and offering great difficulties in the exploration of those regions which were considered most likely to expose the metalliferous veins. Numerous pits had been sunk at random, in the soil and rocks at Eagle Harbor, by the miners under the direction of Mr. Gratiot: but nothing considered worthy the attention of capitalists had been discovered, and the miners were about to leave the country. Mr. De Garmo Jones, of Detroit, had sent up Mr. C. C. Douglass to aid Mr. Gratiot in exploring the country, and he was associated with me in my labors, proving a very efficient assistant. Mr. Frederick W. Davis and Mr. Joseph S. Kendall accompanied me. and assisted in exploring the country for minerals.

It is well known that the results of my examination of the mineral lands on Keweenaw Point were the establishment of the fact that *native copper and native silver* existed there *in regular veins, which could be advantageously wrought by mining operations;* and that in consequence, the capitalists of the eastern States began the enterprises which have resulted in the demonstration of the practicability of mining profitably for copper and silver on Keweenaw Point. I selected the best veins for the establishment of permanent works, collected and analyzed the ores, discovered the nature of all the minerals accompanying the copper and silver veins, and published a brief report of my researches.

In 1845 I was again sent to Lake Superior, and then explored other veins, and pointed out the superiority of the *metallic lodes* over those of the *ores of copper*—a result quite contrary to the general opinion of miners and geologists, but which has been most fully sustained by subsequent experience. As was anticipated by me, the green silicate and black oxide of copper at Copper Harbor soon gave out and was abandoned. The Boston and Pittsburg Mining Company transferred their miners from that place to the metallic copper lode, which I had surveyed in company with Mr. Whitney, at the cliff, on the southwestern branch of Eagle river. This mine is now well known as one of the wonders of the world, affording the largest masses of copper which have ever been seen, and yielding a considerable amount of native silver. I again surveyed those veins I had explored in 1844, and advised the opening of a mine at a place which I named Copper Falls. Operations were forthwith commenced at this place, and a new company was formed by the division of the Lake Superior Mining Company. This mine is still in operation, and has given promising results. The Lake Superior Mining Company sold out their rights to the veins at Eagle Harbor, opened mines on the borders of Eagle river in 1844 and continued their operations for some years at that place.

The foregoing rather copious quotations have been made for the purpose of showing the grounds for the claim that more credit belongs to Jackson than has usually been accorded to him in the literature of the copper regions. Further accounts of his explorations may be found in the report mentioned.

There were several other explorers in the district, at this early date, whose names are on record. The vein afterwards known as the Copper Falls mine was discovered by Joseph Hempstead and C. C. Douglass in 1844 and immediately visited by Jackson. It was on lands held under lease by the Lake Superior Copper Company.

Whitney speaks as follows of the discovery of the Cliff mine, belonging to the Pittsburg and Boston Mining Company (Metallic Wealth, p. 275):

The discovery and opening of this mine formed an era in the history of Lake Superior and are also of high interest to the country, as it was the first mine in the United States, those of coal and iron excepted, systematically and extensively wrought, and at the same time with profit. Besides this, it has a peculiar importance as being opened on a vein bearing copper exclusively in the native state, a feature entirely unknown in the history of mining previous to the discoveries on Lake Superior. * * *

During the summer of 1843 a Mr. Raymond made certain locations in the Lake Superior region, for which he obtained leases, three of which he disposed of to parties in Pittsburg and Boston, who commenced mining in the summer of 1844. The first location made was at Copper Harbor, where the outcrop of a cupriferous vein on what is now called Hays's Point, was a conspicuous object, known to the "*voyageurs*" as "the green rock," and had given a name to that beautiful harbor long before it became the center of the copper excitement. A little work was done here in the autumn of 1844, but on clearing away the ground on the opposite side of the harbor, where Fort Wilkins now stands, numerous boulders of black oxide of copper were found, evidently belonging to a vein near at hand, which was discovered in December, and proved to be a continuation of the one before worked on Hays's Point.

Mining was commenced here immediately; two shafts were sunk, about a hundred feet apart, and considerable black oxide of copper taken out, mixed with the silicate. This was very remarkable, as it is thus far the only known instance of a vein containing this as the principal ore, or in any other form than as an impure mass, mixed with the sulphuret of copper and oxides of iron and manganese, and resulting from the decomposition of the common ore, copper pyrites. This proved, however, unfortunately to be only a rich bunch in the vein of limited extent, and which gave out at the depth of a few feet, although the fissure continued. The workings were entirely confined to the conglomerate, which at that time was supposed to be as favorable to the development of the vein as any other rock. The gangue associated with the black oxide was principally calc spar, and some argillaceous and quartzose matter intermixed. Fine crystals of analcime were found connected with it. Crystallized red oxide and native copper were also obtained in fine specimens. About thirty or forty tons of black oxide were obtained in all, and sold for $4,500. The main shaft was continued down 120 feet, and levels driven each way for some distance without striking another bunch of ore, so that in 1845 the attention of the company began to be turned to exploring their extensive property, and in August of that year the Cliff Vein was discovered by a party of explorers under the direction of a Mr. Cheny.

This vein was first observed on the summit and face of a bluff of crystalline trap, rising with a mural front to the height of nearly 200 feet above the valley of Eagle river at its base. The break or depression made by it in the back of the ridge was quite distinct, and has since been traced to the lake and found marked by ancient excavations. At the summit of the bluff, as I saw it a few days after its discovery, it appeared to be a few inches wide, and contained native copper and specks of silver beautifully iucrusted with capillary red oxide, with a gangue of prehnite. Half way down the cliff, it had expanded out to a width of over two feet, and consisted of numerous branches of laumonite, with a small percentage of metallic copper finely disseminated through it. Of course, at this time, nothing whatever was known of the varying character of the lode in different belts of rock, nor had the trap been supposed by the miners to be the principal metalliferous rock. It is now known that the vein could not be worked with profit in the rock in which it was discovered, namely, the crystalline trap or greenstone, as no vein has yet proved sufficiently metalliferous in that belt of rock to be profitably mined.

Without knowing anything of the entire change in the character of the rock which takes place at the base of the cliff, where there was a heavy accumulation of fragments of rock dislodged from above, and suspecting as little as any one else the unprecedented discoveries about to be made in the metalliferous bed beneath, I advised the clearing away and opening of the vein at as low a point as possible, because it appeared to widen out and improve in depth. A shaft was sunk a few feet, a little below the edge of the bluff, and a level driven into the greenstone a short distance, but nothing was done of importance until the talus at the base of the cliff was cleared away and the vein traced into the amygdaloid. A level was then driven in upon it, and, at a depth of 70 feet, the first mass of copper was struck, a discovery of the greatest interest, since it revealed the presence of a metalliferous belt whose existence had not before been suspected, and showed the extension of the lodes of Lake Superior into belts of rock of different lithological character and the variations in richness attendant on such transitions.

It may be mentioned in passing that this mine paid dividends of about a quarter of a million of dollars between 1849 and 1856.

The following account is given by Whitney of the Phœnix Mining Company:

This company, as originally constituted February 22, 1844, was possessed of seven three-mile-square leases on Keweenaw Point. It was the first organized company of the Lake Superior region, and was called the "Lake Superior Copper Company." Its stock was divided into 1200 shares, of which the proprietors of the leases received 400 unassessable for their interest. The first superintendent was C. H. Gratiot, who had previously engaged in digging lead in Wisconsin. The seven locations, embracing over 40 square miles, were nearly all situated in the very richest portion of the mineral region.

During the summer of 1844, Dr. C. T. Jackson examined several veins which had been discovered on the property by C. C. Douglass and others, and under his direction work was commenced October 22, 1844, on Eagle river, near the place now known as the "Old Phœnix Mine," and carried on through the year 1845, and a stamping mill and crushing-wheels, of a kind suitable for grinding drugs, were erected, but soon proved to be entirely unserviceable. Up to March 31, 1849, when the Phœnix Company was organized and took possession of the Lake Superior Company's property, the latter company had expended $105,-833.40, of which about half was probably for actual mining work, but they had done little or nothing towards developing the value of the property. The principal shaft was sunk on a "pocket" of copper and silver, without any signs of a regular vein, which soon gave out entirely.

The news of these discoveries attracted people from all parts of the land. The excitement increased rapidly, and soon the craze was in full blast. It is thus described by Whitney in his Metallic Wealth of the United States (p. 249):

In 1845 many hundred "permits" or rights to select and locate on tracts of land for mining purposes, were issued by the Government, and 377 leases were granted. Most of the tracts covered by these were taken at random, and without any explorations whatever; indeed, a large portion of them were on rocks which do not contain any metalliferous veins at all, or in which the veins, when they do occur, are not found to be productive.

In 1846 the excitement reached its climax; the speculations in stocks were continued as long as it was possible to find a purchaser, and a serious injury was inflicted on the mining interests of the country by the unprincipled attempts to palm off worthless property as containing valuable veins. But in 1847 the bubble had burst, and the country was almost deserted. Only half a dozen companies, out of all that had been formed, were actually engaged in mining.

The issue of permits and leases having been suspended in 1846 as illegal, Congress passed in 1847, an Act, authorizing the sale of the mineral lands, and a geological survey of the district. In the meantime, while this survey was going on, the companies which had continued their operation made considerable progress. new ones were formed. and lands were purchased by them after bona fide explorations and discoveries of veins: the position and character of the really metalliferous rocks began to be known, and confidence was gradually restored. At the time of the completion of the geological survey. in 1850, and the publication in the following year, of maps of the whole region. on which the range and extent of the geological formations were laid down, copper mining in the Lake Superior district had become established on a firm basis and was rapidly developing.

The discovery of the metalliferous character of the conglomerate was made by E. J. Hulbert. John Hulbert and Amos H. Scott about the 1st of September. 1864. The pit was located by Mr. E. J. Hulbert. who claims to have been fully convinced that the exploration would result as it did. This was a most important discovery and one which altered the entire character of mining on Keweenaw point. It was the beginning of the present regime as contrasted with that in which the veins were wrought for mass copper.

IRON ORE.

Iron ore was discovered in Nova Scotia in 1604, even before the earliest reports of copper from the Lake Superior country. The discovery was reported by the Sieur de Monts, Lieutenant General of Acadia, appointed by Henry IV. of France. In the province of Quebec iron ore was found in 1667: and in Ontario about 1800. The first iron furnace in Canada was established at Three Rivers, near Quebec, about 1630, and is the one mentioned by Kalm, in the work already quoted.

The reports of Dr. Houghton and his assistants C. C. Douglass and Bela Hubbard, for the years 1839 and 1840, and the reports of David Dale Owen for the same years, contain references to iron ores of recent geological age in the southern part of Michigan and Wisconsin. Houghton must even have had some knowledge of iron ores in the metamorphic rocks of the Upper Peninsula, for in his report for 1841 he says; "Although hematite ore is abundantly disseminated through all the rocks of the metamorphic group, it does not appear in sufficient quantity at any one point that has been examined to be of practical importance." On this quotation Brooks remarks (Geol. Sur. Mich., 1869-73, Vol. 1, p. 11):

At this date Dr. Houghton had traversed the south shore of Lake Superior five times, in a small-boat or canoe, on geological investigations.

It is therefore probable that up to 1841 no Indian traditions worthy of credence, in regard to large deposits of iron ore, had come to his knowledge. As there are, so far as known, no considerable outcrops of iron ore, which come nearer than seven miles to the shore of the lake, it is plain that investigations, based on observations taken along the shore only, could have determined no more than its probable existence, which is plainly indicated in the extracts given. Dr. Houghton was not aware of the existence of iron ore in quantity until the return of Mr. Burt's party of surveyors to Detroit in the fall of 1844, his examinations in the interior of the country having been confined to the copper region. Attention at that early period was entirely directed to searching for ores of more value than iron, and it is worthy of remark, that the Jackson and Cleveland Iron Companies, which were the first two organized, were formed to mine copper, silver and gold.

MARQUETTE RANGE.

The actual discovery of iron ore was made by Wm. A. Burt, United States Deputy Surveyor under the direction of Dr. Houghton, who had taken the contract to finish the linear survey and unite with it geological observations of the country traversed. In 1844 Mr. Burt's party, consisting of Wm. Ives, compass-man; Jacob Houghton, barometer-man; H. Mellen, R. S. Mellen, James King and two Indians, John Taylor and Michael Doner, was engaged in establishing township lines and making geological observations in the manner described.

On the 19th of September, while running the east line of Township 47 N., range 27 W., using the solar compass invented by Mr. Burt, remarkable variations in the direction of the needle were noticed. In this connection Mr. Jacob Houghton, one of the party, says:

At length the compass-man called for 'all to come and see a variation that will beat them all.' As we looked at the instrument, to our astonishment the north end of the needle was traversing a few degrees to the south of west. Mr. Burt called out, 'Boys, look around and see what you can find!' We all left the line, some going to the east and some to the west, and all of us returning with specimens of iron ore, mostly gathered from outcrops. This was along the first mile from Teal lake. We carried out all the specimens we could conveniently.

A year later Mr. Burt made the following statement (Jackson's Report, 1849, Part III, p. 852):

The fourteen beds of iron ore above described are the most important ores of iron, for quantity and quality, discovered within the boundaries of this survey. * * * It may be reasonably inferred, that not more than one-seventh of the number of iron ore beds were seen during the survey of the township lines; and if this district of townships be subdivided with care in reference to mines and minerals, six times as many more will probably be found. If this view of the iron region of the Northern Peninsula of Michigan be correct, it far excels any other portion of the United States in the abundance and good qualities of its iron ores.

Mr. Bela Hubbard made a report "upon the geology and topography of the district south of Lake Superior, subdivided in 1845 under the direction of Douglass Houghton, deputy surveyor" (Jackson's Report, *supra cit.*, p. 833). He makes the following statements:

The largest extent of iron ore noticed is in township 47, range 26, near the corner of sections 29, 30, 31 and 32. There are here two large beds or hills of ore, made up almost entirely of granulated, magnetic, or specular iron, with small quantities of spathose and micaceous iron. The more northerly of these hills extends in a direction nearly east and west for at least one-fourth of a mile, and has a breadth of little less than 1,000 feet; the whole of which forms a single mass of ore, with occasional thin strata of imperfect *chert* and jasper, and dips N. 10° E. about 30°. At its southerly outcrop, the ore is exposed in a low cliff, above which the hill rises to the height of twenty or thirty feet above the country on the south. * * * This bed of iron will compare favorably, both for extent and quality, with any known in our country.

As to the discovery of the Jackson deposit, which was the first to be mined in the Lake Superior region, we may quote from the letter from P. M. Everett to Capt G. D. Johnson, dated Jackson, Mich., 1845, and contained in Brook's Report:

I left here on the 23d of July last and was gone until the 24th of October. * * * I had considerable difficulty in getting any one to join me in the enterprise, but I at last succeeded in forming a company of thirteen. I was appointed treasurer and agent to explore and make locations, for which last purpose we had secured seven permits from the Secretary of War. I took four men with me from Jackson and hired a guide at the Sault, where I bought a boat and coasted up the lake to Copper Harbor, which is over 300 miles from Sault Ste. Marie. * * * We made several locations, one of which we called Iron at the time. It is a mountain of solid iron ore, 150 feet high. The ore looks as bright as a bar of iron just broken. Since coming home we have had some of it smelted, and find that it produces iron and something resem-

bling gold—some say it is gold and copper. Our location is one mile square, and we shall send a company of men up in the spring to begin operations; our company is called the Jackson Mining Company.

The actual discovery of the Jackson location was made by S. T. Carr and E. S. Rockwell, members of Everett's party, who were guided to the locality by an Indian chief, named Manjekijik. The superstition of the savage not allowing him to approach the spot, Mr. Carr continued the search alone, resulting in the discovery of the outcrop, which he describes as indicated in Mr. Everett's letter. Previous to the discovery he was led to suppose from the Indian's description, that he would find silver, lead, copper or some other metal more precious than iron, as it was represented and found to be "bright and shiny."

July 23, 1845, articles of association of the Jackson Iron Company were executed at Jackson, Mich., and by these articles Abram V. Berry was appointed the first *President*, Frederick W. Kirtland *Secretary*, Philo M. Everett *Treasurer*, and George W. Carr and Wm. A. Ernst *Trustees*. * * * The location was secured by the permit issued to James Ganson and was described by metes and bounds, commencing at a certain large pine tree, the position of which was fixed by its course and distance from the corner of Teal lake. When the land was surveyed it was bought at $2.50 per acre.

The Cleveland Mining Company was organized in the following year, the location having been discovered by Mr. Abram V. Berry, and obtained by Dr. Dassels of Cleveland. In 1846 Fairchild Farrand explored the Jackson location and mined some ore. The Jackson company erected a forge in 1847 on the Carp river, three miles east of the mine, under the superintendency of Wm. McNair, and the first iron was made February 10, 1848 by A. N. Barney. In 1850, Mr. A. L. Crawford, proprietor of iron works at Newcastle, Pa., took about five tons of Jackson ore to Pennsylvania, and worked it up. Two years later a larger amount was taken to Sharon, Pa., by General Curtis, who visited Lake Superior for the purpose of securing better ore for his furnaces. In 1872 about 70 tons were sent to Sharon; and in 1856 was made the first regular shipment, amounting to 5,000 tons.

The deposit of iron ore at Republic appears to have been first discovered by J. W. Foster and S. W. Hill in the fall of 1848. In the report, presented to C. T. Jackson, of an exploration of the country lying between Lake Superior and Green

Bay is found the following statement by Mr. Foster (loc. cit. p. 775):

After leaving the lake, we saw no exposure of the rocks until we arrived at the north part of township 46, ranges 29 and 30. The river here forms a lake-like expansion, and is bounded on the northeast by a range of hills which rise abruptly to the height of nearly two hundred feet above the water.

We explored this ridge on section 1, township 46, range 30, and found that it was composed, for the most part, of nearly pure specular oxide of iron (fer oligiste). It shoots up in a perpendicular cliff, one hundred and thirteen feet in height, so pure that it is difficult to determine its mineral associations.

We passed along the base of this cliff for more than a quarter of a mile, seeking for some gap through which we might pass and gain the summit. At length, after much toil, and by clambering from one point to another, we succeeded. Passing along the brow of the cliff, forty feet, the mass was comparatively pure; then succeeded a bed of quartz composed of rounded grains, with small specks of iron disseminated, and large rounded masses of the same material enclosed, constituting a conglomerate. This bed was fifteen feet in thickness, and was succeeded again by specular iron, exposed in places to the width of one hundred feet, but the soil and trees prevented our determining its entire width. This one cliff contains iron sufficient to supply the world for ages, yet we saw neither its length nor its width, but only an outline of the mass. Its bearing could not be accurately determined, but was inferred to be north of west and south of east, with a northerly dip of 85°.

This same deposit is also described in similar terms in Foster and Whitney's Lake Superior (Part II., p. 22). In his first annual report Mr. Wright states that this property was originally "explored" by S. C. Smith, and entered by James St. Clair in 1854. The Republic Iron Company was not organized until October 20, 1870, and the first ore was shipped in 1872.

The great demand for iron occasioned by the Civil War caused the iron interests which were in operation at that time to assume a very successful aspect. Development progressed rapidly, and although expenses were large, the demand for ore was constant, and the prices high, so that permanent and prosperous cities like Negaunee and Ishpeming were started and sustained by the iron ore mining industry of Marquette county.

MENOMINEE RANGE.

The earliest reports of iron ore on this range are furnished by those same early geologists and explorers, J. W. Foster and S. W. Hill, whose trip across the country from Lake Superior to Green Bay in the fall of 1848 has already been mentioned. It seems almost incredible that their observations should have lain for so long a period unverified and forgotten, while the search for iron was prosecuted in other parts of the same region. But it was actually more than twenty years before these deposits were rediscovered and thoroughly explored. Foster's first account reads as follows (Jackson, loc. cit. p. 777):

About two miles southeast of the lower falls [of the "Twin Falls" on the Menominee], near S. 30, T. 40, R. 30, there is a large bed of specular iron ore associated with the talcose and argillaceous slates. It makes its appearance on the north side of a lake, and can be traced a mile and a half in length, and in places is exposed one hundred feet in width. It bears nearly east and west, and in external characters resembles that of the iron mountain before described. This bed was first discovered by John Jacobs, from whom I derived the information, and may be regarded as the southern limit of the iron. The distance from this point to the most northerly point where iron was discovered [on the Marquette range] is more than 50 miles in a direct line. Below the falls there are heavy accumulations of drift, so that the subjacent rocks are rarely seen; and this bed of iron ore, if it cross the river, is effectually concealed.

The limestone was also observed, and a bed of marble indicated on the map which accompanied the report. The iron ore was compared with that of Elba, New York, and Missouri, and said to excel them all in value and favorable location. It was pointed out that the natural outlet would be by way of Bay de Noquet on Lake Michigan, the place where Escanaba is now situated, and that it was entirely practicable to construct a road to that point. In the "Report of the Commissioners of the Geological Survey" of Wisconsin for 1858, are the following remarks by Col. Chas. Whittlesey:

In 1850 I passed up the Menominee as far as Irwin falls, and examined the rocks to the east of the river in Michigan. Here the magnetic and specular ores were found, and beautifully veined marbles. The system of Magnesian slates extending from Carp river, on Lake Superior, westward and southwestward, which embraces the metamorphic limestones and the iron, was then traced to the state line of Wisconsin.

During the explorations of the present year, in tracing that system within this state across the Menominee river, I had the satisfaction to find that it produces here both iron and marble, in quantities that are inexhaustible.

I cannot in this note, nor until the analyses are completed, give an idea of the value of the ores, but I am satisfied that whenever a cheap mode of transportation is provided they will attract notice. Both the iron ores and the marbles exist on both sides of the river convenient to water power that is unlimited. A considerable part of the deposits of iron have hard wood near at hand suitable for coal.

Further mention of the "iron ridge" southwest of Lake Antoine and near Lake Fumée may be found in Foster and Whitney's Lake Superior, Vol. II., pp. 30, 31, 1851. On page 28 there is given a section taken from the manuscript of Col. Whittlesey, showing specular iron interstratified with saccharoidal limestone near a branch of Cedar river and near Little Bekuenesec falls on the Menominee river. It is also stated, in this connection, that Mr. W. A. Burt crossed a low ridge of iron ore in 1846, not far from the corner of townships 41 and 42, between ranges 29 and 30. This was not subsequently met with in running the township lines. This ore is, however, shown on the geological map of 1873.

In 1866 Thomas and Bartley Breen, of the town of Menominee, discovered the deposit which afterwards became known as the Breen mine, on sec. 22, T. 39-28. No further explorations were made until 1870, when the "fee" of the property had passed into the hands of the discoverers and Judge Ingalls and S. P. Saxton. Mr. Saxton then commenced the first active mining operations recorded in the region by sinking several test pits, and cutting two long trenches across the formation.

In 1867 the region was visited and examined geologically by Dr. Hermann Credner, of Germany. His description, in German, was published in 1869, and contained frequent references to the iron ores.

The first systematic exploration was begun in 1872 under the immediate supervision of our distinguished President, Dr. Nelson P. Hulst, at that time the agent of the Milwaukee Iron Company, the chief promoters of which were Mr. J. J. Hagerman and Mr. J. H. Van Dyke of Milwaukee. That the company had made a good choice in their selection of an explorer was soon proven, by the discovery of the Vulcan and West Vulcan mines. Mr. Lewis Whitehead, who was Dr. Hulst's chief woodsman, was no less energetic than his superintendent, and soon had a road cut from the Breen to the Vulcan and camps erected at the latter place. In 1873 Mr. John L. Buell explored the Quinnesec property and carted the first ore (fifty-three tons) to Menominee, where it was smelted by the Menominee Furnace Company.

The panic of 1873 put a damper on operations for a time. But in 1877 the Menominee Mining Company, of which Dr. Hulst was a member, purchased the leases of the Milwaukee Iron Company, and again started the Doctor on the search for ore. He was again successful, this time discovering the celebrated Chapin mine. This was in 1878; and in 1880 the first shipments were made, amounting to 34,556 tons. The discovery of the Norway mine soon followed (in August, 1878), and thereafter the new range was entered fully in the list of ore producers from Lake Superior.

PENOKEE–GOGEBIC RANGE.*

The magnetic iron ore belt of northern Wisconsin was first noted in 1848 by Dr. Randall, assistant geologist to Dr. David Dale Owen, while following the Fourth Principal Meridian northward.

In Owen's "Report of a Geological Survey of Wisconsin, Iowa and Minnesota" there is a "Geological Report of that portion of Wisconsin bordering on the South Shore of Lake Superior, surveyed in the year 1849," by Charles Whittlesey. On pages 444-447 of this report (published in 1852) is a description of the "Magnetic Iron-beds of the Penokie Range." Analyses of iron ore found there are quoted which show from 56.3 per cent. to 66 per cent. of metallic iron, and the following statements are made:

* H. V. Winchell, "A Bit of Iron-Range History," *American Geologist*, March, 1894.

The bed of magnetic iron ore south of Lac des Anglais is of extraordinary thickness,—twenty-five to sixty feet. * * * In the wild and deep ravines where the Bad river breaks through the range, there is a cliff of slaty ore, most of which comes out in thin, oblique prisms, with well-defined angles and straight edges, probably three hundred feet thick, including what is covered by the talus or fallen portions. I estimate more than one-half of this face to be ore; and in places the beds are from ten to twelve feet in thickness, with very little intermixture of quartz. There are portions of it not slaty, but thick-bedded.

The geological occurrence is fully figured and described, and the similarity of this ore to "the extensive mines or rather mountains of iron ore in Michigan, described by Houghton, Burt, Jackson, Foster and Whitney" is also mentioned. The idea of exploitation on a large scale is conveyed in the last paragraph:

The position of the best exposures of ore which I saw is such as to require from eighteen to twenty-eight miles of transportation to reach the lake. The nearest natural harbor is in Chegwomigon bay, about twenty-five miles from the central part of the Penokie range.

The interesting origin of the name "Penokie" was given as follows by Col. Whittlesey in an article on "The Penokee Mineral Range" read before the Boston Society of Natural History in July, 1863:

In the Chippeway language the name for iron is *pewabik;* and I thought it proper to designate the mountains, where this metal exists in quantities that surprise all observers, as the "Pewabik Range." The compositor, however, transformed it to *Penokie*, a word which belongs to no language, but which is now too well fastened upon the range by usage to be changed.

Soon after the publication of Dr. Owen's report, the excitement of 1845–6 in reference to copper was repeated in reference to iron Preemptors followed the surveyors, erecting their rude cabins on each quarter-section between the meridian and Lac des Anglais, a distance of eighteen or twenty miles. The iron belt is generally less than one-fourth of a mile in width, regularly stratified, dipping to the northwest conformable to the formations, and having its outcrop along the summit of the second or southerly range.

So much iron was found there that he intended to call it the "Pewabik" range in 1850, even before the government survey of the region.

This paper was accompanied by a geological map of the range prepared by Whittlesey in 1860, on which the crest of the range and the outcrops of iron ore are marked with wonderful accuracy.

But Whittlesey was not the only geologist who observed and described the mineral wealth of this region. In 1858 Edward Daniels, one of the State Geological Commission, and prior to that time State Geologist, visited the Penokee-Gogebic range and mentions it as follows in the Commissioner's report for 1858, pp. 10, 11:

The mineral resources also promise richly. The most important of these are the great deposits of iron ore found in the Penokie Mountains, about thirty miles inland from the head of Chegwomigon Bay. These iron beds follow the mountain ridge through several townships, having a direction a little north of east. * * * * The ore is principally the magnetic and brown oxide, with traces of specular iron, and occurs in seams parallel with the stratification, varying from a mere line to fifty feet in thickness; it is of good quality, well located for quarrying, and practically inexhaustible.

Another well-known scientist who saw and appreciated the ore deposits of this range was Dr. I. A. Lapham, afterward State Geologist of Wisconsin. He visited the Penokee district with Daniels in 1858. His account of the trip may be seen in the Trans. Wisconsin State Agricultural Society, Vol. V, 1858–59. He there gives what is perhaps the first published map of the range, and speaks highly of the iron ore he saw there. In a report made by Dr. Lapham to the Wisconsin and Lake Superior Mining and Smelting Company, dated November, 1858, and published in pamphlet form in 1860, we find the following:

It will be seen that we have already discovered good ore in such quantities as to be practically inexhaustible, situated at points accessible to water power and having bold fronts, rendering it comparatively easy to be quarried. For many years to come only the richest and most accessible ores can be brought into use, rejecting—at least for the present—all such as have too large a proportion of silica, and such as are not in a condition to be easily and cheaply removed from the natural bed.

Further full accounts of the Penokee-Gogebic range are to be found in Volume III of the Wisconsin Geological Reports for 1873–79, pages 100–166.

A brief description of this range by R. Pumpelly and T. B. Brooks published in the report of the Michigan geological survey for 1872 seems to have attracted considerable attention.

This report was accompanied by a map on which the belt of iron-bearing rocks is delineated in a general way.

In 1873 J. H. Brotherton conducted explorations which very closely located the iron formation for the canal company. Subsequent work of development has borne testimony to the accuracy of his field locations, all the mines since found in the district examined by him being on or very near the line at that time determined.

The first discovery of soft ore in situ and in large quantity is said to have been made by Capt. Nat. D. Moore, during the season of 1880. This was on section 13, T. 47–46, Michigan. Capt. J. P. Pease commenced explorations on the adjoining section (14) in June, 1881, for the Cambria Iron and Steel Co., and partially developed the Colby mine. Actual mining was begun here in October, 1884, by Capt. Moore, and the first ore was shipped in six flat cars over the Milwaukee, Lake Shore and Western Railway to Milwaukee, and thence to Erie, Pa. Under the management of Mr. Joseph Sellwood this mine surpassed all predecessors in the amount of ore shipped during the first three years after it was opened.

The Sunday Lake mines were found by Geo. A. Fay, who conducted explorations in 1881 and 1882 for D. H. Merritt and others of Marquette, Mich.

During the fall of 1882 test pitting was started by Capt. Jas. A. Wood for Mr. A. L. Norrie, on the S. ½ of S. E. ¼, Sec. 22, T. 47, R. 47. Ore was found almost immediately, and the great Norrie mine is the result of subsequent explorations on the same ore body.

The wave of mining stock speculation which fairly inundated the northern states during the two years following the discovery of these iron mines is of too recent date to require description. Suffice it to say that the production from the new range was simply phenomenal, doubling and trebling with unparalleled rapidity, and constituting one of the most remarkable chapters in the mining history of this remarkable country.

VERMILION RANGE.

The first account of iron ore on the Vermilion range appears in the report of State Geologist H. H. Eames, published in 1866. On page 11 is this account:

The Iron Range of Lake Vermilion

is on the east end, on the stream known as Two River, which is about sixty feet wide. * * * This range is about one mile in length; it then ceases, and after passing through a swamp, another uplift is reached, from two hundred and fifty to three hundred feet high. The iron is exposed at two or three points between fifty and sixty feet in thickness: at these points it presents quite a mural face, but below it is covered with detritus of the over-capping rock. On this account its exact thickness could not be correctly ascertained. The ore is of the variety known as hematite and white steely iron, and is associated with quartzose, jasperoids and serpentine rocks. It generally has a cap rock of from three to twenty feet thick. A little to the north of this is an exposure of magnetic iron of very good quality, forming a hill parallel with the one described.

The hematitic iron has a reddish appearance from exposure to atmospheric influence; its fracture is massive and granular, color a dark steel gray. The magnetic iron ore is strongly attracted by the magnet and has polarity, is granularly massive, color iron black.

At the request of the legislature of Minnesota Col. Charles Whittlesey made a "Report of Explorations in the Mineral Regions of Minnesota during the years 1848, 1859 and 1864," published in Cleveland in 1866. In this report is a map of Vermilion Lake and the Mesabi Iron Range. It also contains, on page 10, an announcement of the discovery of iron ore at the former locality by Eames. Here Col. Whittlesey gives it as his opinion that workable iron ore exists near enough to Lake Superior to render it of practical value.

The first "shot" was put in the ore at Vermilion Lake by Geo. R. Stuntz and John Mallmann in 1875, on the "south ridge." In 1884 the Duluth and Iron Range Railroad was constructed from Lake Superior to the mines at Tower, and mining was begun under the direction of Capt. Elisha Morcom. Afterwards, with a change of ownership, in 1886, the management passed to Mr. D. H. Bacon, under whose supervision subsequent discoveries were made and the mines developed into one of the finest plants in the country.

The mines at Ely were first opened by Mr. Jas. Sheridan and his associates in 1886, but were soon turned over to the present owners, under the superintendence of Mr. Jos. Sellwood and his mining captain, John Pengilly. The record of the Chandler has been a most creditable one. Further detailed accounts of the Vermilion range may be found in "The Iron Ores of Minnesota," Bulletin No. 6 of the Geological Survey of Minnesota, which was written in 1890 and published in 1891.

MESABI RANGE.*

In 1850 J. G. Norwood mentioned iron ore as occurring at Gunflint lake (D. D. Owen's report of Wisconsin, Iowa and Minnesota, p. 417), and stated that it appeared to be in the eastward continuation of the hills known farther west as the Mesabi, and which extended to Pokegama falls on the Mississippi river. He did not notice ore in sufficient quantities to impress him with its value as a merchantable ore deposit, but simply noted its occurrence near the west end of the lake.

H. H. Eames, the geologist mentioned above, was the first to note iron ore on the Mesabi range and consider it of any value. In his report of 1866, published the following year, is an account of the ore on the western end of the range, at Prairie river, together with several analyses, showing it to be of good quality. Mr. Eames took steps to secure title to this property and develop it; but the time had not yet come for such an enterprise to be successful.

Favorable mention is made of the Mesabi in various other geological reports, between that time and 1891. N. H. Winchell and A. H. Chester described it at some length in the seventh, ninth, tenth and eleventh reports, and the State was urged to take steps to have it developed. In the volume on the iron ores of Minnesota, however, may be found the most elaborate dis-

*This spelling of the name "Mesabi" is adopted because it conforms with the usage of the state and national geological surveys for many years, and is in accord with the decision of the National Board of Geographic Names.

cussion of the rocks of this range. The views held at this time, before the actual discovery of any of the numerous deposits since opened up, are well expressed in the following quotations, op. cit., pp. 112, 160:

> They [the ores of the Mesabi] are destined to play a very important part in the future development of the iron industry of the state. They occupy fourfold the area that is occupied by the Keewatin ores [Vermilion range], and they are nearer the ore-shipping points as well as the iron-using markets. It is on account of this high promise of future productiveness that they are fully described in this bulletin. * * *
>
> There can be no reasonable doubt that in Minnesota, about the western and northwestern confines of the Lake Superior basin and extending westward to the Mississippi river, there will yet be mined in the Mesabi range even greater quantities of hematite than have been taken from that marvel of mining districts, the Penokee-Gogebic range, which blazed out with such a brilliant record only a few years ago.

The first persistent exploration of the Mesabi range for iron ore was made by the Merritt brothers, Lon and Alf., of Duluth, Minn., and to them in largest measure must be credited its unprecedentedly rapid development, and to a certain extent the disastrous consequences to the iron ore interests of the entire lake Superior region during 1893. The Mountain Iron mine was found on the 16th day of November, 1890, by a crew of workmen under Capt. J. A. Nichols. In August, 1891, the next large deposit was discovered by John McCaskill, Capt. Nichols and Wilbur Merritt; this has since developed into the Biwabik group of mines. In 1892 two railroads were built to the range, and in 1893 the shipments amounted to 620,000 gross tons, a record for the first full year's shipments that has never been equalled.

CANADIAN IRON ORE.

Deposits of iron ore are known to exist in Ontario, north of lake Superior. The McKellar brothers of Fort William, have done more than any others to discover the iron ores of that vicinity. Although not yet thoroughly explored by shafting or drilling, it is probable that there is a considerable amount of merchantable ore in the Thunder bay district which will be of value when the country is more thickly populated. It is not likely that it will ever enter into serious competition with the ore of those portions of the lake Superior region situated in the United States, owing to its poorer quality and greater cost of production. So far as these deposits are at present developed they do not compare favorably with those on this side of the boundary line.

SILVER.

Having devoted considerable space to a description of our two most prosperous and profitable mining industries, it remains for us to mention more briefly the discovery of silver and gold.

The occurrence of native silver mixed with the copper of Keweenaw Point and the north shore of the lake was noticed at an early date, and has already been referred to under the head of copper. The only mines around Lake Superior that have been wrought for any length of time for silver alone are on the north shore, around Thunder Bay. The discovery of silver grew out of explorations for copper. In 1846 Mr. William Logan spent the summer in an examination of the Canadian shore of the lake. During the same season Mr. Forrest Sheppard conducted the first explorations for the Montreal Mining Company, starting on May 2 from Montreal with a small party, which was soon increased to the number of eighty or more. The coast was examined from Sault Ste. Marie to Pigeon river, a distance of about 500 miles, and eighteen locations were selected. Each location was five miles in length and two in width, thus containing ten square miles of territory. One of these locations included Silver Islet, on which the silver was not discovered, however, until 21 years later. Prince's location, west of the Kaministiquia, on Thunday Bay, seems to have been the scene of the first discovery of silver in what was at that time a large quantity. The vein had a width of 14 feet, composed of calcite, barite and amethystine quartz, with a metalliferous streak in the middle. Two shafts and an adit level were opened, and masses of silver several pounds in weight were taken out. It is reported that the silver carried an appreciable amount of gold. This work was abandoned about the year 1850.

In 1856–1857 the Montreal Mining Company, on the advice of their superintendent, Mr. E. B. Borron, attempted to develop a mine on their location at Point Mamainse. There were several veins which made a good surface showing of native copper, chalcopyrite and galena, with silver both native and in the lead sulphide. Five shafts were sunk to depths varying from 14 to 60 feet on the most promising leads. But the veins did not hold out in depth, and operations were suspended in 1857.

The Prince and Mamainse mines, however, seem to have been more highly valued for copper than for silver, and the first discovery of silver of any consequence was made by Mr. Peter McKellar in the autumn of 1866, at what afterwards became the Thunder Bay mine. About a year later the Shuniah (later called Duncan) vein was found to be silver-bearing by Mr. John McKellar and Mr. Geo. A. McVicar. This was in May, 1867. Work was prosecuted on these veins in 1869 and 1870, the expenditures at the latter mine having amounted to about half a million dollars for a total yield of $20,000, before the final suspension in 1882.

The events leading to the discovery of silver on Silver Islet and the account of the "find" are given as follows by Mr. Thomas Macfarlane (Trans. Am. Inst. Min. Eng., vol. VIII, 1880, pp. 227, 228):

It was, in all likelihood, the McKellar discoveries, together with the imposition by the Ontario government of a tax of two cents per acre on Lake Superior mining lands, which prompted the Montreal Mining Company to begin a systematic exploration of their northwestern locations. For twenty-two years these had been allowed to lie almost entirely neglected. Several of them were indeed visited and explored by Mr. Pilgrim of Sault Ste. Marie and the late Mr. Harrick, P. L. S., but the results were not such as to encourage the company to proceed to active mining operations. Indeed, during the greater part of this time, the company's resources were taxed to the utmost in developing and working the Bruce copper mines. It may safely be asserted that in doing this they experienced a dead loss of $400,000, a fact which is abundantly sufficient to account for the unwillingness of the board and shareholders to risk further capital in mining operations. The causes above given were, however, enough to induce them to incur a moderate outlay for exploring their lands, and early in 1868 I was employed by the company to take charge of a party for this purpose. * * * * On the 16th of May our exploring party, consisting of six men besides myself, arrived in Thunder Bay, on board the steamer Algoma, which was heavily freighted with men and materials for working the Thunder Bay Company's mine.

overcome his reluctance to reveal his discoveries, and was conducted nearly to the spot and then told to find the veins himself, which was not a difficult matter.

There have been occasional discoveries of silver in other parts of this district; and companies have been formed to operate mines on surface showings of greater or less attractiveness. One of the most persistent attempts to mine silver ore was made in the vicinity of Ontonagon, Michigan. Mr. Austin Corser, of that place, is said to have discovered silver ore in situ in 1856. When the land was surveyed, in 1870, he procured a preemption on the S. W. ¼, Sec. 14, 51–42, on Little Iron river, about a mile from Lake Superior. In 1872 a mining craze of the regulation style set in. It reached its greatest intensity in 1874, and subsided in the following year. A stamp mill with amalgamators was erected near this place in 1875 by the Ontonagon and Superior Mining Companies, under the direction of Mr. F. W. Crosby, but only about 50 tons of ore were milled. The boom collapsed, and the mines shut down, the Cleveland being the last to quit, in 1876.

GOLD.

Although mines of the yellow metal are neither numerous nor large producers individually in this section of the county, they are found on both shores of the lake, and it is not improbable that they will increase in number and productiveness during the next decade.

There are reasons for believing that the first discovery of gold was made by Dr. Douglass Houghton in 1845 not far from the present town of Negaunee. The story is told by Mr. S. W. Hill, and a voyageur named Antoine Du Noir. They agree in the statement that Dr. Houghton wandered away from camp one day and returned about dark with a bag full of specimens in which native gold was plainly visible. He told them that they were in a gold country, and that he should not be surprised to find quantities of it in the Huron hills. A piece of the quartz found at that time was worn as a pin for many years by Mr. Jacob Houghton, a brother of the doctor. The notes of this season's work were lost in the lake at the time of Dr. Houghton's death, but the accounts of these explorers are considered trustworthy, and the discovery of the Ropes vein in this same vicinity at a later period is strong corroborative proof of their truthfulness.

In 1865 a gold boom was started in Minnesota. The ore was reported by State Geologist Eames and others to have been discovered in paying quantity at Vermilion lake, 75 miles north of Duluth. A wagon road was laid out to the new Eldorado: new towns were started: shafts were sunk, and a stamp mill was taken up there and set up on Trout river. The very land subsequently found so valuable for iron ore, where the hard hematite and jasper stood out in bald knobs, a hundred feet high, was taken for gold claims. The veins, however, proved to contain more pyrite and pyrrhotite than gold; and by 1867 the country was deserted, iron deposits and all.

In 1871 gold ore was found by Mr. Peter McKellar at Jackfish Lake, near Lake Shebandowan, about 70 miles northwest of Port Arthur. It was developed into the mine called the "Huronian," and worked during part of 1884 and 1885. In 1883 a 10-stamp mill was erected, but was operated only a short time, owing to the expense of getting supplies in so remote a region.

Another gold-bearing quartz vein was found by Mr. Archibald McKellar, on an island in Partridge lake, west of Lac des Mille Lacs, in 1872; and in 1875 nuggets of gold were discovered by Mr. Donald McKellar in a quartz vein at Victoria Cape, on the western side of Jackfish Bay, north shore of Lake Superior. Nothing of importance was done to develop either of these mines.

Gold was found on Lake of the Woods in 1878 or earlier, and there has been more or less mining for the precious metal in that region ever since.

In 1881 Mr. Julius Ropes noticed gold in a vein about six miles northwest of the city of Ishpeming. Regular mining was begun here in October, 1882, and during the following summer a 5-stamp mill was erected. In 1884 a 25-stamp mill was completed and put in operation. This is the only genuine gold mine in Michigan, and *its* history has not been an enviable one.

In 1885 considerable excitement was caused by the discovery of gold three miles west of the Ropes mine on land belonging to the Lake Superior Iron Mining Company. Some beautiful samples of ore were obtained, but the average did not warrant the expenditure necessary to develop a mine.

CONCLUSION.

In closing this brief history attention should be called to the fact that the majority of our metalliferous belts were discovered by official geologists in the performance of their assigned duties. In many instances the very ore deposit was found, examined, accurately located and described with a thorough appreciation of its value, a quarter of a century or more before any advantage was derived from the information thus early given to the public.

Especial mention should also be made of the distinguished services rendered to the sciences of mining and economic geology by the wonderful man from whom this beautiful city takes its name. Dr. Douglass Houghton may be justly styled the Father of Mining on Lake Superior. To his indomitable enterprise and courage no less than to his versatile and colossal intellect is due the credit for the right start which was made; and in many ways his broad-gauged generous spirit is still discernible in the conduct of affairs around us.

We have attempted merely to mention the discovery of our mineral deposits, and not to sketch their subsequent development. But it were not becoming in me to close without calling attention to three other classes of creditors to whom our obligation is large. Our present condition of prosperity has been rendered possible first, by our brethren from Cornwall, Austria and other parts of Europe who, leaving their home surroundings, have journeyed to our shores and devoted years of hardest manual labor in delving for Nature's hidden treasures. Their lives have been passed underground, in dark and often dangerous galleries, while the fruits of their labors have been largely reaped by others.

We are greatly indebted in the second place, to the liberal policy of our State and National Government regarding technical education. Such institutions for scientific training as the one located in this city exert an incalculable influence for good on the material conditions surrounding us as well as on the lives and characters of our inhabitants.

Third and finally, our obligation is great to the mining engineers and superintendents who have planned and directed the development of these natural resources. In a new country, confronted with new problems, with unforseen difficulties constantly arising, they have met each obstacle as it arose, and with industrial genius reaching almost to the sublime, have snatched victory at times from the very jaws of defeat, until our mining industry stands as it does to-day—in many respects without a parallel on the face of the globe.

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TWO NEW GEOLOGICAL CROSS-SECTIONS OF KEWEENAW POINT.

BY L. L. HUBBARD.

Gentlemen of the Lake Superior Institute:

I propose to show you this evening two cross-sections of Keweenaw Point, that are new as far as the public is concerned, one of which will appear in Volume V of the Reports of the Michigan Geological Survey, now in the hands of the printer. In connection with these sections, it may be of interest to those of our fellow members from other parts of the state to hear something about the geology of this district, and to listen to a brief resumé of the principal theories* that have been advanced to explain the relative position of the different geological formations on and near Keweenaw Point and to determine their age or ages.

Lake Superior, as you all know, is a geological basin whose rim is to a great extent lined by volcanic rocks, and in some places by a sandstone of Cambrian age. The principal exposures of these volcanic rocks, which are associated and intèrcalated with sandstones and conglomerates, begin at Nipigon Bay on the Canadian shore and extend along the Minnesota shore down into Wisconsin, and from there northeasterly nearly 300 miles to the extremity of Keweenaw Point. Isolated exposures also occur on the eastern shore of the lake, and at Isle Royale and on smaller islands in the lake. The part of this formation to which I shall more particularly call your attention to-night is the northern half of Keweenaw Point, cut off from the southern half by

*These theories are discussed at length by Irving and Chamberlain in Bulletin No. 23 of the U. S. Geol. Survey, 1885, from which I have drawn largely in the preparation of this paper.

a great fault along the line of Portage Lake. Here, the copper-bearing or Keweenawan rocks occupy, in general terms, a belt flanked on the west by a sandstone of disputed age, and on the east by a sandstone recognized as the equivalent of the Potsdam, which latter formation is exposed further east along the shore of the lake, and also on the west, at the Apostle Islands. The edges of the belt of copper-bearing rocks have not yet been definitely ascertained along the entire length of the belt, but at one point, at Eagle River, are known to be about six miles apart, which gives the formation at that point, if there be no repetition by faulting, a thickness of over 15,000 feet, exclusive of an outer belt, the Upper Keweenawan of Irving, that is there buried under the lake, but emerges further northeast, as well as southwest. Further east this thickness, according to Irving, increases to 25,000 feet.*

The rocks that compose this belt are, as already stated, volcanics, sandstones and conglomerates, alternating in beds of different thickness that dip northwesterly to northerly at angles varying between 55° at Hancock, 52° at the Peninsula mine, 38° at Calumet, 46° at the Allouez mine, 31° at Eagle River, and 26° at the Central mine, nearly thirty miles northeast of us. The strike of the belt follows approximately the trend of the Point, being at Hancock N. 33° E., at the Tamarack mine N. 33° 15′ E., at Eagle River N. 62° E., and changing to east and even south of east as we approach the extremity of the Point. Owing to the flattening of the dip, the *horizontal width* of the beds increases as we go northeast. Later we shall see that their absolute thickness also increases, up to a certain point, in the same direction. South of Portage Lake for some distance the copper belt is largely covered by drift, and has been comparatively little exploited, until we approach the vicinity of Greenland and Rockland near Ontonagon, which was the center of mining activity forty years ago. It may not be out of place here to say that the copper deposits worked on Keweenaw Point at the Cliff and Phœnix mines and beyond, and at the southern end of the range, opposite

* The Copper-bearing Rocks of Lake Superior. Monograph V, U. S. Geol. Survey, 1883, p. 166.

the Porcupine Mountains, were generally in transverse fissure veins; in the vicinity of Ontonagon they were largely in so called veins nearly parallel with the formation, and in this neighborhood they are in beds of the formation, both volcanic and sedimentary.

The Keweenawan formation, beyond the Allouez mine, is marked on the west by a ridge 500 or 600 feet high, sloping gradually on its western side down to Lake Superior, its eastern side being bold and in many places precipitous. This is called the "Greenstone" Range. A deep valley separates it from the Bohemian Range, which lies nearer the shore of Keweenaw Bay. Further northeast the Greenstone Range on its southern slope shows terrace-like protrusions, while the Bohemian Range (including Mount Houghton at Lac La Belle) has more rounded contours. As we shall see later, the rocks that form the bulk of this range are different in character from those of the Greenstone Range.

Before proceeding to a detailed description of the beds that compose the copper-bearing series, it may be well to speak of their geological relations to the sandstones that flank them on Keweenaw Point. These latter I shall call the eastern or Potsdam, and the western sandstone. The eastern sandstone in general has a flat dip to the northwest, and in Douglass Houghton Creek, near the head of Torch Lake, where naturally exposed, it *appears* to run under the copper-bearing rocks. At Wall Ravine, nearly two miles further north, it is nearly vertical, and at Bête Grise Bay, near the end of the Point, it appears to overlie the volcanic rocks unconformably.

Dr. Jackson thought that the sandstones and conglomerates of Keweenaw Point are older than the volcanics or traps interbedded with them, and thought that the former were, in one case at least, intruded by the traps, which then flowed over them. The trap rocks "caused the elevation of the sandstones along the line of disruption." The conglomerates are the production of aqueous forces.

Foster and Whitney thought that the eastern or Potsdam sandstone is associated with the beds of conglomerate and trap, the trap having been poured out like lava sheets, during the deposition of the sandstone, from a series of fissure veins along the line of the present copper-bearing rocks, in other words, that the latter are conformable and coeval with the Potsdam. The greater part of the material of the conglomerates, both pebbles and matrix, was ejected at the time of the different eruptions, and is not therefore of aqueous origin, although the pebbles later may have been rounded by water action. Along the present line of junction between the eastern sandstone and the traps there was formed a deep-seated fissure through which the "unbedded" traps of the Bohemian Range were afterwards protruded, tilting the bedded traps and their associated conglomerates to the north and the sandstone to the south. Near Portage Lake there was no protrusion, and there was little or no disturbance of the sandstone, while on the other hand the edges of the trap were lifted along the line of fissure.

Pumpelly thought that the copper-bearing rocks were laid down conformably on the Huronian, and both were then tilted by the Azoic. Then an immense erosion followed, after which the eastern sandstone was laid down against a shore-cliff of copper-bearing rocks. This view seemed to him to be confirmed by the unconformability of the Potsdam on the copper-bearing rocks in localities away from this vicinity. While the Potsdam was being deposited, a gradual subsidence of the copper-bearing rocks was going on. He does not appear to have admitted the existence of a great fault along the line of contact of these rocks.

Rominger thought that the sandstones on the east and west sides of Keweenaw Point are identical, *i. e.*, that they were once continuous over the trap; that there has been a rupture on the east side and a subsidence of the sandstone there and an uplift of the traps. The fault, therefore, occurred *after* the deposition of the *greater part* of the eastern sandstone. The copper-bearing series is therefore older than the eastern sandstone, although not separated from it by a great unconformity. To the subsidence of the eastern portion of the sandstone and the underlying formations Rominger attributes the fact that none of the lower beds of the trap series are found on the Huronian slates at L'Anse, for the latter were not submerged until the time when the upper horizontal beds of the sandstone were forming.

Credner thought that the intercalated sandstones and conglomerates in the trap series are probably Lower Silurian, and belong to the same age as the rocks alongside of them (*i. e.* the eastern sandstone).

Wadsworth thought that the traps are old lava flows, and that they with their interbedded sandstones and conglomerates form one and the same series with the eastern sandstone. His view seems to be based on occurrences at the falls on the Douglass Houghton and Hungarian creeks, respectively, and to be supported by the fact, that at those localities the eastern sandstone *apparently* passes conformably under the trap series; that, as he supposes, it is baked and indurated at the junction by the overlying trap; that it is interstratified with the trap beds, and contains pebbles from them. In his later publications he admits, however, the evidence of faulting elsewhere along the eastern exposure of the traps.

Irving, after some modifications of his views, finally thought with Chamberlain that the copper-bearing rocks are older than the eastern sandstone; that they were faulted along the present line of contact of the two; that after the formation of this fault, the sandstone was laid down, and then a further slight faulting occurred, which bent the edges of the sandstone layers *downwards* at Douglass Houghton Creek, and *upwards* at Wall Ravine two miles north of it. This later faulting would seem not to have affected to an equal degree the relations of the rocks at Bête Grise Bay, still further north, where the sandstone abuts unconformably against the trap formation, and dips S. E. Irving further satisfied himself that the Bohemian Range, the so called "unbedded trap" was not a later eruption than the "bedded trap" further northwest, but was the base of the series, its rounded contour being due to a steeper dip of the beds. The eastern sandstone near the line of junction is crowded with angular fragments of Bohemian Range rocks.

It is not my purpose to discuss these different views to-night, but I may state briefly a few of the objections that have been advanced against several of the theories. One objection to Foster and Whitney's view of the age of the Bohemian Range, I have just given. Both Pumpelly and Irving thought that the view that the traps and the eastern sandstone were parts of one formation requires too great an erosion, the latter placing it at four miles vertically. If such an erosion did take place, where, they ask, are the trap-beds that once overlay the eastern sandstone in Keweenaw Bay? Only one small outcrop of trap, which might be a part of those beds, has been found at Silver Mountain, six miles east of the contact, and fourteen miles from the head of Keweenaw Bay. We also find patches of Trenton limestone lying conformably on the eastern sandstone at points ten to thirteen miles north of Silver Mountain, in T. 51, R. 34 and 35. Again, this erosion, if it took place, would not have left, in front of a friable sandstone, a linear or slightly wavy cliff without recesses or outliers.

The induration of the eastern sandstone, it has been admitted, may be due to an enlargement of the quartz grains by crystallization. No baking nor induration is noticeable of a seam of clay directly under the bed of trap at the junction in Douglass Houghton creek, but the clay is soft and looks like a product of faulting. The trap series along the contact has a substantially uniform northwesterly to northerly dip, the eastern sandstone near by being "warped and angulated," and quite out of harmony with the traps.

Irving laid stress upon the fact that the eastern sandstone is substantially horizontal. In this he has been shown by the Michigan Geological Survey to have underestimated the dips, for at many points quite remote from the line of junction the sandstone dips quite uniformly towards the traps, sometimes as much as 10° or 12°. The dissimilarity of the topmost sandstones on the east and on the west of Keweenaw Point has been pretty generally taken for granted, that on the east having been considered more quartzose and less feldspathic than the other. Some sandstone strata near the canal at the head of Portage Lake much resemble the eastern sandstone, although they appear to be less quartzose, containing, according to Irving only 30% of quartz.

In view of the fact that Irving made the eastern sandstone about 300 or 400 feet thick, it may be of interest to note that a well sunk by the Calumet and Hecla Company at Lake Linden, five years ago, goes through 1,500 feet of the eastern sandstone, without reaching the bottom of that formation. The sandstone is described in the record as red, or "solid, red" with several streaks of white, and two or three occurrences of marl. The feldspathic nature of the sandstone at Portage Entry (38%) and the occurrence of marl as shown in this well, may indicate a nearer approach in character of the eastern and western sandstones than has hitherto been admitted.

ROCKS OF THE KEWEENAW SERIES.

The volcanic rocks which, associated with conglomerates, compose most of the beds northwest of the Bohemian Range on Keweenaw Point, are popularly known as traps. They are diabases or melaphyrs, basic rocks, each flow or bed being nearly always divisible into three parts that merge into one another, the lowest generally dark, hard, compact and to the naked eye apparently unaltered; the highest, lighter in color, much altered, and filled with round or elongated amygdules of minerals foreign to the rock. This part is called amygdaloid, and the amygdaloid cavities were formed by the distension of gas bubbles near the surface of the lava stream at the time the lava flowed. They are sometimes filled with copper, alone or with other minerals, which are supposed to have been deposited in the rocks by infiltration, after the rocks were laid down. These two divisions, traps and amygdaloids are the only ones usually recognized by the mining men. Pumpelly and others made a third division midway between these, and called it *amygdaloidal melaphyr*. In this part there were probably no amygdules originally, but by a decomposition of portions of the rock itself, in shapes that resemble amygdules, and the formation *in situ* of minerals derived from this decomposition, the rock becomes spotted or a *pseudo-amygdaloid*. Irving has recognized a fourth variety, at the base, also amygdaloidal, but it is of very subordinate interest. Often the passage from trap to amygdaloid may be very gradual, and it is quite possible that owing to differences of erosion or to other causes the top of the lava flow at points not far apart may differ somewhat, so that in one mine we may find one heavy bed of amygdaloid that corresponds to an alternation of trap and amygdaloid in another adjoining it. For this reason, in our correlation of beds the conglomerates, with few exceptions, are the only sure "datum planes" from which we can measure our distances and the thickness of the beds, and even the conglomerates may dwindle to mere seams. This may be ascribed to local variations in the original deposition of the conglomerates, and perhaps in some degree to a faulting or sliding along these conglomerates as planes of weakness.

The North or "bedded trap" Range is, as I have already said, sometimes called the "Greenstone Range," because of the fact that it is largely made up of beds of what was supposed to be "greenstone," or diorite. The diorite of the Iron District is not identical with this "greenstone." Where the former contains *hornblende* the latter contains *augite*, often in large individuals, that under the microscope show themselves permeated with minute feldspar crystals. These clusters reflect the light in such a way that the rock has been aptly called "lustre-mottled," and on weathering its surface becomes warty. This greenstone, then, is a melaphyr or olivine-diabase, diabase differing from melaphyr in being completely crystalline, while melaphyr shows some residual matter that was originally uncrystallized, or glass. Inasmuch as augite alters readily to hornblende, it is probable that most of the diorites of the Iron District were also originally diabases. The "greenstone" or diabase on Keweenaw Point is generally much less green than the diorite, and when weathered does not have the same lustre.

The olivine diabases grade through coarser kinds to a gabbro. This rock, or one like it, occurs in the Bohemian Range, but no deposits are now worked on that part of the Point, nor ever have been to any extent, and less is known of the rocks there, and of their structural relations, than of those in the more western range.

One more basic eruptive rock should be mentioned. In diabase the form of the augite is generally determined by the feldspar crystals, *i. e.*, the augite fills up completely the *angular* spaces left between the feldspars. When the rock is fine-grained, and the augite is in *rounded* grains whose form is not determined by the feldspar; in other words, when the feldspar becomes more abundant relatively to the augite, and the rock becomes more acid, we have a *porphyrite*. In this rock there often is more or less unindividualized base, or glassy matter (a sign of rapid cooling off of the lava). This rock is either light colored or dark colored. A well-known bed in this region, the so-called "ash-bed," is of this kind of rock, its upper part being very ropy, twisted and vesicular. The Copper Falls and Atlantic Mines, at extremities of this district, work in this bed.

The foregoing embrace the basic rocks, which form by far the largest part of the copper-bearing series. With them are a few occurrences of acid rocks, more or less crystalline, the (quartz) porphyries. These have a red brown to brown, very fine-grained matrix, in which are crystals of feldspar, and sometimes of quartz. In a few cases the quartzless porphyries show a tendency to vesicular structure, and thin sections show flowage lines, but generally these rocks are quite hard and compact.

Augite-syenite is also found in the Bohemian Range. It has generally a granitic structure, and pebbles of it occur largely in the Albany and Boston (Allouez) conglomerate.

All of these acid rocks play a great role in the conglomerates, in which they are accompanied by fragments of sandstone and of trap (which latter is generally altered), sometimes cemented together by calcite. These fragments are often amygdaloidal, even the acid rocks in rare instances, as just stated, showing this peculiarity, and being more or less permeated with copper.

The sandstones are yellow or brick-red, and they are sometimes *in situ* impregnated with very fine copper.

If now we begin at the east margin of the trap series, as exposed, we find among the lower layers some acid eruptives, more that are basic, and with them several conglomerates. The latter, near the base of the series, are not numerous nor very thick. As we approach the middle of the series the conglomerates increase, and finally, near the top of the series, largely predominate. The "Great" conglomerate, above the greenstone at Eagle River, is about 2,200 feet thick. Beyond it, overlying some eruptives, is the "Outer" conglomerate, Irving's Upper Keweenawan, which at Eagle River and further east is about 1,000 feet thick, but increases to 9,000 feet at Portage Lake, where it is composed almost wholly of sandstone and shales. Irving has estimated the thickness of the lower division of the Keweenaw series at one point near Montreal River at 35,000 feet and that of the upper division at 12,000 feet, and thinks certain beds and groups of beds are persistent for 150 miles. You have seen that the formation on Keweenaw Point dips northwest. On the opposite side of the lake it dips southeast, and at the east and west ends of the lake, where exposed, it dips toward the lake. Now, since these conglomerate beds must have been laid down in a horizontal position, the traps overlying them must, as a rule, have been spread over them while the conglomerates were substantially in their original position. The acid volcanics are supposed to be more viscous at the time of their extrusion, hence we should not expect to find them at such great distances laterally from their vents, as we should the more basic rocks, the traps, which were more fluid, and probably had a temperature of nearly 2,500° F. The question has never been settled just where the traps were ejected, but it has been thought to have been somewhere in the lake, or on its shores where dikes are now seen. On the persistency of the beds laterally from their vents, if these were linear, will depend in great measure the question whether these rocks, covering so large a territory, were poured out from one central vent, or came from independent points widely separated, and at different times. This question may be of vital importance to the miner, for if we can establish the homogeneity of the copper-bearing series, we may be able to find the Calumet conglomerate or the Quincy amygdaloid somewhere on Isle Royale. If, however, we can establish no parallelism between beds at distant points, we may have to conclude that different foci of eruption existed. This would be more likely to affect the amygdaloid deposits than those in the conglomerates, which are likely to have been laid down pretty uniformly over the Lake Superior basin, but to have been exposed with the former to subsequent varying dynamic forces. In either of the cases above mentioned we shall probably in the end find the most important question to be, "Where did the copper come from, and what conditions regulated its deposition where we now find it?"

One of the cross-sections that I have to show you to-night was made from data furnished the Geological Survey by the officials of the Calumet and Hecla and Tamarack Mining Companies, respectively. On a plane passing through the Red Jacket shaft of the Calumet and Hecla mine at right angles to the strike of the Calumet conglomerate, have been projected the beds found in several cross-cuts of that mine, together with those cut by shafts No. 3 and No. 4, North Tamarack. We have been unable to ascertain the exact position of the Red Jacket shaft, but by scaling from a map of sections 11 and 14 we find that it is approximately 1,300 feet east of the projection of Tamarack No. 3 on said plane, and that the latter shaft is about 1,900 feet north of said plane. The Calumet conglomerate, as shown by the Calumet and Hecla inclined shaft, has, in the diagram, a dip of 38° in the upper levels of the mine, and 37° 30′ from the 36th level down. The Red Jacket shaft has recently cut the Calumet conglomerate at a depth of 3,287 feet (collar of shaft to foot wall), or about 50 feet above the point required by the above dips. This need not surprise us, if we remember that the dip of the formation flattens as we go deeper, and also as we go northeast. The most widely separated cross-cuts on our diagram are 7,458 feet apart, along the strike of the lode. The dip near the south end of the Calumet and Hecla location was estimated by Mr. Bolton, a former engineer of the Calumet and Hecla mine, to be 39¼°. The dip of this bed in the Tamarack mine is in places as low as 36°. In this connection it may be said that the dips in several of the beds mined in this district, and in fact their strikes also, are subject to local variations each way, the contact surfaces of the beds evidently being wavy. This is markedly true of the Osceola amygdaloid.

From the work that Marvine did for the Geological Survey, under Pumpelly,* we learn that there are seventeen conglomerate beds in the Keweenawan near Portage Lake which have been traced for different distances along their outcrops, one of them, the Allouez, with such success that its position at many points between Eagle River and Portage Lake has been located with more or less probability, if not with certainty. This conglomerate serves as a good datum line, by the aid of which we are enabled to identify several other conglomerates that are seen here and there, and to calculate their approximate position, as well as that of others, at points where they are covered by drift. In the Red Jacket shaft this bed is 8 feet, in Tamarack No. 4, 5½ feet, and in No. 3 only six inches, thick.

Of the seventeen conglomerates mentioned, we probably have in the section before us, beginning on the east, the Kearsarge (Marvine's No. *11*)†, the Calumet (No. *13*), the Allouez (No. *15*, our bed No. 48 in Tamarack shaft, No. 3), the Pewabic West (No. *16*, our bed No. 15), and the Hancock West (No. *17*, our bed No. 4), beside the Osceola amygdaloid and the "Ashbed" (bed No. 5). The North Star conglomerate (No. *12*), which should lie between the Kearsarge and the Calumet conglomerates, and the Houghton conglomerate (No. *14*), which should lie between the Calumet and the Allouez conglomerates, seem to be wanting in our section.

The lowest bed of the "greenstone" group (bed No. 47), immediately over the Allouez conglomerate, appears in the Tamarack shaft to be 190 feet thick, and in the Red Jacket shaft 277 feet thick. We shall see later that the corresponding bed in the Peninsula (old Albany and Boston) mine is only 27.4 feet thick. That the thickness of any particular bed should vary materially at even such short distances as 2,300 feet is not strange. We have just seen a greater relative variation in the case of the Allouez conglomerate. On the other hand we see

*Geological Survey of Michigan. I, Part II, p. 47.
†Figures in *Italics* refer to Marvine's conglomerate beds.

that the Osceola amygdaloid is remarkably uniform in the three cross-cuts of the Calumet and Hecla mine. If, however, we compare corresponding beds or groups of beds in the two shafts, we find discrepancies that can be accounted for only on the supposition that the observations in the Calumet and Hecla shaft were not as thorough, or that the distinctions between trap and amygdaloid were not as sharply drawn as in the Tamarack shaft. Otherwise, unless we admit that the rate of decomposition that has prevailed along the lines of the two shafts has been different, and even *greater* in the *deeper* parts of corresponding beds, which is improbable, we must ascribe the apparently great preponderance of amygdaloids in the Tamarack shaft, which correspond to traps in the other, to a difference in the original chemical, or physical, *i. e.*, amygdaloidal character of each bed at different intervals along its original surface.

The zone of amygdules might be found to extend down further from the original surface of the beds in lavas that contained gaseous matter in great quantity or under a high tension than they would in others with gas in smaller quantity or under less tension, but in the *same* bed their distribution would be likely to be relatively uniform, certainly for short lateral distances. The chemical composition of any bed would also be uniform for short distances.

Let us examine, in the Tamarack shaft, the relations between the amygdaloidal beds and their underlying traps. We are struck by the fact that in the upper part of the shaft many of the former are quite thick, while the traps are rather thin. Although it may not be safe to assume in every case that an amygdaloidal bed and its immediately underlying trap constitute what was originally one lava flow and the whole of one flow, we find that in the Tamarack shaft the beds taken by pairs show the following relations of amygdaloid to trap, viz: from the surface to the Allouez conglomerate, bed No. 48, 1:2.20; below the Allouez conglomerate, 1:3.63. If we leave out the three heavy trap beds with their overlying amygdaloids, our figures become 1:1.425 and 1:2.27, respectively—which does not alter the relation. In short, the deeper we go the less amygdaloidal rock we meet. Near the surface we also find, near together, thick and thin amygdaloids, thin and thick traps. These facts suggest the conclusions that the amygdaloidal alterations of the rocks are largely of the pseudo-amygdaloidal kind; that they are due, in part at least, to a sub-surface decomposition after the beds had begun gradually to assume their present position, and that the amount of these alterations must depend largely upon the chemical character and upon the texture of the different beds, and upon the amount of their exposure to agencies of decomposition. We know that the more porous conglomerates have been greatly decomposed, for we find in them pebbles of porphyry, which in general had a much greater resisting power than the amygdaloids, sometimes covered with a shell of copper, the interior being a crumbly, greenish to purplish mixture of epidote, chlorite and a kaolinitic substance, in which well formed crystals of feldspar and quartz grains and crystals are disseminated.

There seems to be no uniformity in the nature of the beds that immediately overlie and underlie the conglomerates. From Marvine's cross-sections we learn that in 23 cases conglomerates or sandstones are overlain by trap, and in 11 cases by an amygdaloidal rock. The preponderance of trap next above a conglomerate we might expect: but if these rocks are all extrusive, we should hardly expect to find trap immediately below conglomerate in 17 occurrences as against only 13 of amygdaloid.

Our second cross-section this evening is through the Peninsula mine (the old Albany and Boston) which has done a good deal of work on a bed supposed to be identical with the Allouez conglomerate. The following tables show some data derived from the two cross-sections and from others made by Marvine. Figures taken from the latter source are in Italics, and figures in parentheses denote the absolute thickness of the several beds:

THICKNESS, IN FEET, OF BEDS AT DIFFERENT POINTS.

No.	Conglomerates.	Central Mine.	Eagle River.	Allouez Mine.	Calumet and Tamarack Mines.	Peninsula Mine (Albany & Boston).	St. Mary's Location.	Atlantic Mine (S. Pewabic).
17	Hancock West	....	(*1-6* in)	....	Tam. No. 3 (2.4)	....	(*32*)	......
16	Pewabic West	....	(*1-4* in)	....	Tam. No. 3 (27.8) Red J. (8)	....	(*11*)	......
15	Allouez	(*15-20*)	....	(*15-20*)	Tam. No 3 (0.5) Tam. No. 4 (5.5)	(20)	(*35*)	(*26*)
14	Houghton	....	....	....	Wanting.	(28.4)	......	......
13	Calumet	....	....	....	(1-30, av. 13)	(3.2 fluc.) (4.7 congl.)	......	......
11	Kearsarge	....	....	....	(64)	....	......	......
	Amygdaloids—							
	Ashbed. Bed No. 6	....	(*92*)	....	Tam. No. 3 (27)	....	......	(7 +)
	Osceola	....	....	....	(49)	(29)	......	......
	Greenstone— Lowest bed immediately above Allouez conglomerate	....	(412)	....	Red J. (277) Tam. No. 3 (189.6)	(37.8)	......	......

The Peninsula mine cross-section shows an indurated sandstone (by the miners called "jasper" 110 (67.7) feet west of the Allouez conglomerate. In Tamarack shaft No. 1 there is found (160) feet above the Allouez conglomerate a bed called "jasper," separated from the former by an amygdaloid and a trap, the latter being about (137) feet. We have no sample from the latter bed, and cannot say whether it is like the bed in the Peninsula mine.

I would also call your attention to the fact that no trace of the Houghton conglomerate, No. 14, nor of the thin conglomerate just west of it in the Peninsula mine, occurs in our Calumet-Tamarack cross-section. The former should be expected to occur just above or below bed No. 60. You will also notice that the Calumet and Allouz conglomerates in the former mine, but not in the latter, are accompanied by fluccans.

The following diagram and figures will make apparent the relative positions of several of the beds we have had under consideration to-night, and the thinning of the beds between them. The scale across the beds is twice that of their length. The rate of thinning per 100 feet of strata between two points is found by dividing the rate per 1,000 feet by the *average* thickness in hundreds of feet between those points:

THINNING BETWEEN No. 17 AND No. 16.

	Total thinning.	Rate of thinning per 1,000 ft.	Rate of thinning per 1,000 ft. per 100 ft. of strata.
Eagle River (*767*) 64,100 ft.*	211 ft.	3.29	.49
Tamarack No. 3 (556) 37,800 ft.	58 ft.	1.53	.29
St. Mary's (*498*)			

THINNING BETWEEN No. 16 AND No. 15.

	Total thinning.	Rate of thinning per 1,000 ft.	Rate of thinning per 1,000 ft. per 100 ft. of strata.
Eagle River (*1,622*) 64,100 ft.	355 ft.	5.538	.389
Tamarack No. 3 (1,267) 37,800 ft.	108 ft.	2.86	.236
St. Mary's (*1,159*)			

THINNING BETWEEN No. 15 AND No. 13 *(inclusive of Houghton conglomerate)*.

	Total thinning.	Rate of thinning per 1,000 ft.	Rate of thinning per 1,000 ft. per 100 ft. of strata.
Kearsarge (*1,432*) 10,000 ft.	123 ft.	12.3	.90
Calumet and Hecla (1,309) 28,000 ft.	205 ft.	7.32	.607
Peninsula (1,104)			

* These figures, derived from Marvine (Geol. Survey of Mich., I, Pt. 2, p. 60), denote distances along the formation between points at which the thickness is given.

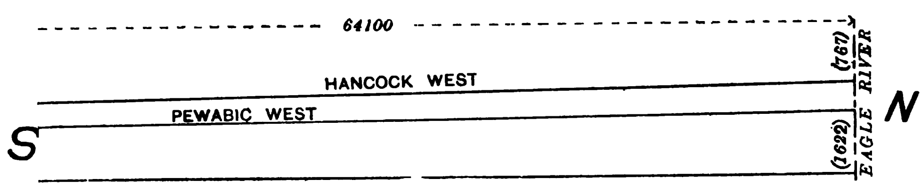
BETWEEN No. 13 AND OSCEOLA AMYGDALOID.

	Total thinning.	Rate of thinning per 1,000 ft.	Rate of thinning per 1,000 ft. per 100 ft. of strata.
Calumet (449) 28,000	92 ft.	3.28	.81
Peninsula (357)			

BETWEEN No. 13 AND KEARSARGE CONGLOMERATE.

	Total thinning.	Rate of thinning per 1,000 ft.	Rate of thinning per 1,000 ft. per 100 ft. of strata.
Kearsarge Mine (*1,064*; 10,000	134 ft.	13.4	1.34
Calumet (930)			

If Marvine's estimate of the distances respectively between the Allouez, Calumet and Kearsarge conglomerates at the Kearsarge mine is correct, these conglomerates approach each other, between



TE FIGURES FROM MARVINE
)TES THICKNESS OF BEDS

great deal of faulting. As Marvine suggested, the general thinning of the beds toward the south points to an eruptive center for this district to the north or northeast of us. The great thickness of many of the beds near Eagle River, and the prevalence in that district of seams of clay or "slides" a few inches thick, in place of conglomerates which further south attain a thickness of 11 to 35 feet, may well indicate a large amount of faulting. The fluccans over the Calumet conglomerate and over the Allouez conglomerate in the Peninsula mine, point to faulting also at that place, and these are factors that tend to make uncertain any figures we may deduce from cross-sections constructed from the data of a few explorations. That faulting has occurred in this district, also across the formation, we have abundant evidence in many of the mines, especially far out on the Point.

The total thickness of the conglomerates of the Keweenaw series has been estimated at 8,000 feet. Hence there must have been an immense time required to complete the series, and as the outer beds are pretty flat, the lower beds were gradually sinking while the upper beds were still forming, and there must have been time for an enormous erosion. This fact, with the faulting along the formation, should seem to throw great weight in favor of the theory that the eastern and western sandstones are, after all, formations of the same age, separated by a great fault.

INTERIOR OF QUINCY STAMP MILL, MICH.

ORE DRESSING ON LAKE SUPERIOR.*

BY F. F. SHARPLESS.

The dressing of Lake Superior copper-bearing rock generally begins underground, and it is here that careful work is the source of considerable economy in producing the metal. The nature of the copper deposits is such that it is comparatively easy to keep the bed and the wall rocks separate from each other, to hoist them separately, and thus keep the totally barren rock from passing under the stamps and onto the jigs.

Again, large areas of almost barren ground are frequently found in the beds themselves. These are generally allowed to remain untouched, or when partially removed by drifting and sinking, are kept separate from the metal-bearing portions, and if hoisted go immediately to the rock piles.

Upon reaching the surface, the ore immediately begins to undergo the first steps of the dressing operation in the rock house. At some of the mines the rock and shaft house form one and part of the same building, while at others the rock house is independent and the ore from all shafts comes for treatment to one rock house.

Whichever method is followed, the ore is dumped from the skips or cars onto grizzlies; these are gratings built of iron bars or timbers faced with iron. The bars are placed from four to six inches apart and lie at an angle of 45° or less.

At the Atlantic Mine, the rock passing through the grizzlies falls upon a second screen made up of inclined iron bars, one and one-half inches in diameter, placed four inches apart, and sloping in a direction at right angles to the first grizzlies. The rock passing between the small bars drops without further treat-

*Condensed from the original paper, which was profusely illustrated by lantern slides.

ment into the ore bins; that passing over these bars is thrown by hand into a 14½-inch Blake breaker, where it is reduced to pieces of about 3½-inch diameter, dropping thence into the ore bins. The ore and rock passing over the first grizzlies is hand sorted, the poor rock being thrown upon the dump, and the copper-bearing into 24-inch Blake breakers, which reduce it to about 3½-inch pieces and drop it into the ore bins.

At the new rock and shaft house of the Quincy Mine the ore falls from the skips upon cast iron gratings raised only slightly from the horizontal. The material passing through this grating goes direct to the underlying ore bins; that which is too large to pass through is drawn out on the floor of the rock house. The smaller pieces containing little copper are thrown into one of two jaw breakers standing on either side of the gratings.

Larger pieces are thrown into a larger breaker, which feeds to two smaller breakers standing below it. Pieces too large for the breakers are broken under a drop hammer on the same floor. At the Quincy Mine mass copper is of such common occurrence that special provision is made for caring for large chunks. It is impossible to break these masses of copper and expensive to cut them up, and yet it is not economical to send them to the smelters without previous cleaning. The larger pieces that have not been cut up in the mine are cleaned under the drop hammer spoken of. Smaller pieces are treated under a steam hammer built for this purpose. The sorting of the mass copper must be done with care, for if allowed to get into the breakers they will clog or something will break.

Returning again to the Atlantic Mine: From the ore bins at the rock house the ore is loaded through chutes into cars holding about five tons each, and it is then taken in trains of twenty cars to the mill on Portage lake, a distance of about three miles. At the mill the cars are dumped into bins located under the track, and about seventy-five feet distant from the mill. These bins, in turn, discharge into small cars which empty automatically into the ore bins in the upper part of the mill. At the other mines the cars used are generally larger, running up to ten, fifteen, and even twenty tons.

The arrangement of the dressing apparatus and the relative position of the ore bins is practically the same in all of the mills. The ore bins occupy the upper portion of the mill and feed by gravity into the mortars of the stamps; on the floor next lower than the stamps are placed the roughing jigs, a little lower than these the finishing jigs, and lower than the last, or on the same level, the slime tables.

The method of feeding the ore to the stamps is the same in all the mills. The ore runs constantly from the lower edge of the pockets onto a shaking tray, the lip of which is above the mortar of the stamp. By the side of this hopper a man stands constantly, breaking large pieces of the ore, picking out any pieces of mass copper that he may notice, and regulating the supply of ore as the working of the stamp may require. Three patterns of steam stamps are used at the present time—the Ball, the Leavitt, and the Allis. The Ball is the oldest, and we might say the father of the others.

The accompanying table will give an idea of the amount of work done, but not of the merits of the stamps. The character of the rock from the different mines varies so much that unless we had the various stamps in the same mill, and working on the same rocks, a comparison would be valueless.

	Atlantic.	Tamarack.	Calumet and Hecla.
No. of stamps	5	5	22
Pattern of stamp	Ball.	Allis.	Leavitt.
Foundations	Solid and spring	Solid.	Solid.
H. P. per stamp, about	140	----------	150
Force of blow in tons, about	21	721.4	20
Tons crushed per day, per stamp	210	300	----------
Character of rock	Amygdaloid.	Conglomerate.	Conglomerate.
Water used per ton	30 tons.	35-40 tons.	----------
Life of shoe	3,000 tons, or 14¾ days.	3 to 4 days, worn from 700-200 lb.	5-6 days.
Life of screen, about	8,820 tons, or 42 days.	3-5 weeks.	1 month.
Character of screen	4 cast steel plates, 9½" x 48" No. 11, slot holes 5-16" long	4 plates, steel 9" x 25" x 1-12", 3-16" punched holes.	Steel plates 4-16" round holes.

It will be noticed from the table that the capacity of the steam stamps is enormus, and that the amount of water that is required to remove the crushed rock from the mortar is also very large.

The rock is crushed to pass holes varying in diameter from 3-16-inch to 5-16-inch, depending upon the character of the rock under treatment. Crushing this fine does not liberate all the copper from its gangue; in fact, it would be almost impossible to crush the conglomerate fine enough to liberate all of its metal. The size of the opening in the screens used at the various mills has been determined by experiment to be the most economical for that particular ore. Crushing finer would, of course, decrease the capacity of the stamp and cause loss by wear of particles already liberated, hence it is best to use as coarse a screen as the ore will permit. By no means all of the copper that yet remains attached to particles of rock is lost; a large portion of this material, called the ragging, is caught on the jigs and either returned to the stamps or treated in some grinding machine.

The wear of the shoes, made of chilled cast iron, though it appears very rapid, is actually very small when compared with the amount of work done by them.

The Leavitt mortar discharges on four sides, while the others discharge on two; this without doubt increases the capacity of the Leavitt stamp.

The amount of water used for washing and carrying away the tailings is so large that few of the mills are fortunate enough to possess a natural supply adequate to the demands. During the wet season a large portion can be supplied from neighboring streams, but the pumping engines form no insignificant part of the mill plant.

As the ore passes through the screens of the stamp it is collected by a splash-box, and drops into a launder leading to the separators. This launder divides the ore stream into three equal portions, one portion being delivered to each of the three separators. The separators at the Atlantic mill consist of a trough about 15 feet long, 18 inches wide and 18 inches deep. Near the bottom, and at the front of each separator, are four small pipes discharging upon the screens of 4 jigs just opposite them. In the axis of the separator and opposite each outlet is a vertical $1\frac{1}{2}$-inch pipe, supplied with water from above and opening downward about two inches from the bottom of the separator. Between each of these four pipes lies a bed of copper, deposited in the regular working and allowed to remain there. As the ore enters the separator it passes over these beds of copper, coming successively in contact with the rising currents generated by the supply pipes mentioned. The head of water in each successive pipe is less, so that the heavy particles of copper and gangue will fall into the cavity around the first, and pass through the small opening in the front and spread themselves upon the roughing jigs. In the second cavity less heavy particles will fall, in the third still smaller grains, and that ore which passes the fourth division of the separator is classed as slime, and goes at once to the settling tanks.

The separation accomplished by the device used at the Calumet is also very incomplete, so that the size of the material coming upon the various screens cannot be given further than has been stated above. Following each separator are four so-called roughing jigs, each having two screens; thus the ore from each separator is treated by a set of eight screens, each set of eight doing exactly the same work. The hutch work from the roughing jigs passes to twelve finishing jigs, placed at a lower level, all of which do different work.

We will now follow the course of the ore in detail. The figures on the drawing are only used to make the description clearer, and have no reference to the system of treatment. The unbroken lines represent overflow; the broken lines represent the direction of the flow from the lower portion of the apparatus.

The mixed ore coming onto screen No. 1 is there jigged; the hutch work, passing through the screen, is discharged into a launder leading to finishing jig No. 25. A large percentage of the copper contained in the ore collects upon screen No. 1. This is removed by hand at such intervals as the amount collected may require. The tailings from No. 1 screen flow upon

No. 8, where they are re-jigged. The hutch work from No. 8 passes into the same launder as that from No. 1; but little copper is collected upon No. 8, so that the removal of the bed occurs less often. The tails from No. 8 pass into the tail launder of the mill, and are subjected to no further treatment.

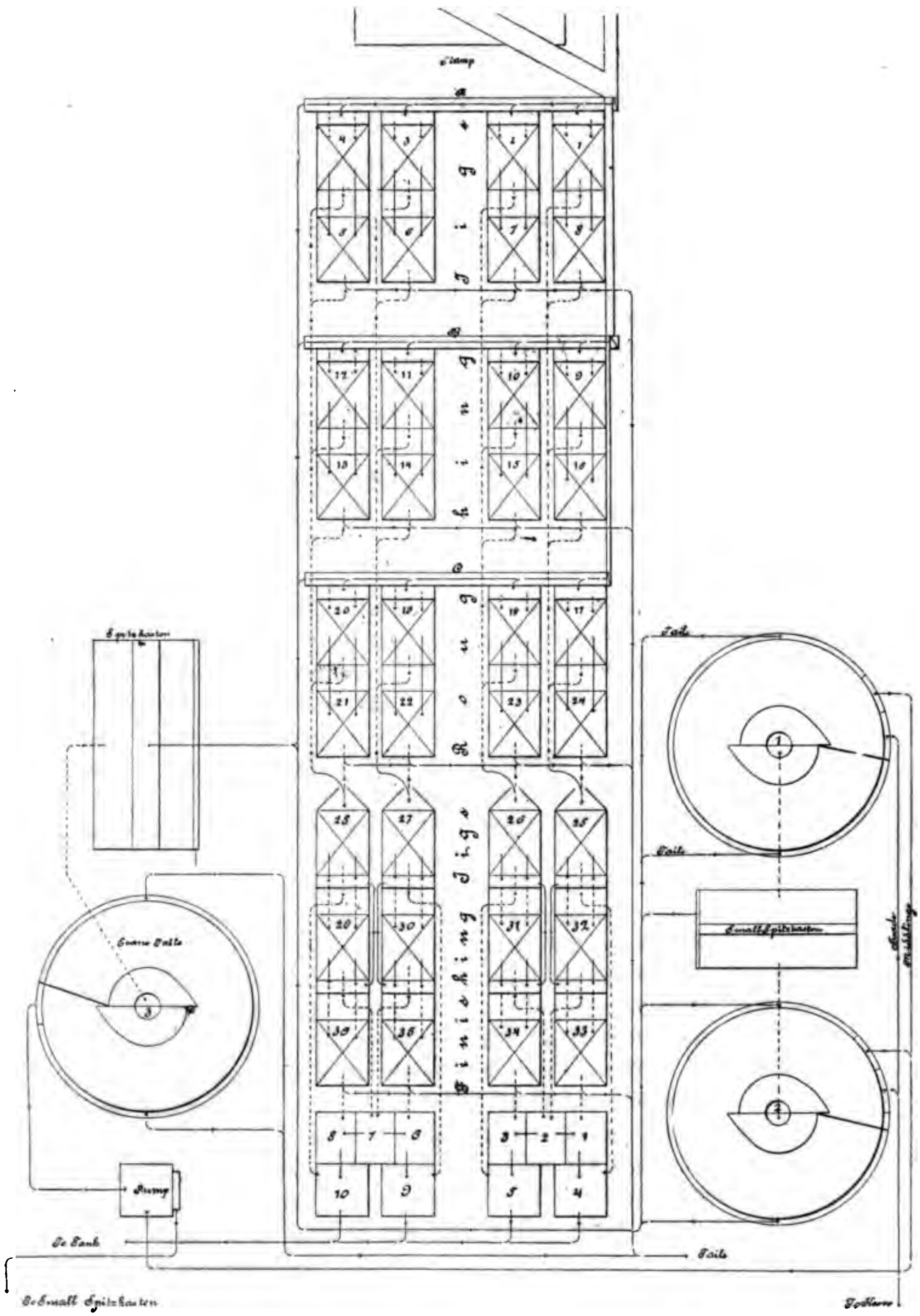
The ore flowing upon Nos. 2 and 7, 3 and 6, 4 and 5 is treated as that on Nos. 1 and 8. The hutch work of Nos. 2 and 7 passes to the finishing jig No. 26; that of Nos. 3 and 6 goes to No. 27; and that of Nos. 4 and 5 to No. 28. Less copper collects upon Nos. 2, 3 and 4 than upon No. 1, and practically none collects upon Nos. 5 and 6; these two screens do, however, collect a large amount of ragging, and make considerable hutch work. The ragging is removed by hand at intervals and returned to the stamps. The tails from Nos. 5, 6 and 7 are discharged into the tail launder.

The other sixteen roughing jigs make the same separations as the first eight, their hutch work passing to the same finishing jigs, and their tailings going to the tail or waste launder.

The ore flowing upon finishing jig No. 25 is there jigged, the hutch work goes to box No. 4; the bed of copper collecting upon the screen is occasionally removed, and the tailings flow into a small settling box at the lower end of the jig. The overflow from this settling box is carried to the box below No. 32, while the settlings pass to jig No. 32. The hutch work from jig No. 32 passes to box No. 2; the copper is occasionally removed from this screen; the overflow passes to a second box at the lower end of the screen.

The settlings from the last-mentioned box pass to jig No. 33, the hutch work from which goes to box No. 1, and the overflow into the waste launder; it is very rarely found necessary to remove the copper from the screen.

By following the lines of the drawing it will be seen that the work of the jigs No. 26, 31 and 34, 27, 30 and 35, 28, 29 and 36 is practically the same as that given for Nos. 25, 32 and 38, the only difference being that every successive screen is of smaller mesh than the preceding, *e. g.*, the screens on jigs Nos. 25, 26, 27 and 28 have about the following mesh: 10, 12, 16



Treatment Of Copper Rock.

Atlantic Mill, Houghton, Mich.

L. S. Roper.

May 1892

and 20, respectively; while the screens on jigs Nos. 32, 31, 30 and 29 are 16, 20, 25, and 25 mesh, respectively. The copper is seldom removed from any of the screens of the finishing jigs, for but little collects there. The office of the finishing jigs is is to make hutch work.

The mineral from boxes Nos. 3, 6 and 8 is re-jigged on the finishing jigs, that from the other boxes is tossed in keeves. The tossing produces two classes of mineral; the upper or lighter class is re-jigged, while the lower or heavier class is barrelled for smelting.

The slime treatment of this mill appears quite intricate to the uninitiated, so we will describe the treatment of but a small portion of it, which will, however, be sufficient to indicate the method of working.

The slime, when it leaves the separator, passes to a settling tank. The tails from this tank, which consist principally of muddy water, go into the tail launder of the mill, or are used in washing the slimes during their subsequent treatment. The settlings from the tank are distributed over half of an Evans slime table, the other half of the table being supplied with water only. This table makes but two classes, namely heads and tails. The tails go into the waste launder, while the heads go to a small centrifugal pump. From the pump the heads pass to a small settling tank above the second floor of the mill. The overflow from this tank goes back to the first table to be treated again. The settlings pass to one or two Evans tables, called the finishing tables. The finishing tables are of slightly different construction from those on which the slimes are first treated, making three classes, namely, heads, middlings and tails. The tails go back to the first table, the middlings are retreated on the finishing tables, while the heads are tossed in a keeve.

As a result of the first tossing two layers are made; the upper one is sent again to the finishing tables, the lower is transferred to a second keeve. Two layers result from the second tossing; the upper goes back to the first keeve, while the lower is barrelled for smelting.

The drawing shows but a small portion of the plan of the mill.

The relative positions of the jigs have not been altered, but those of the tables have been changed to show to the best advantage.

SLIME TABLES, QUINCY STAMP MILL.

SINKING "C" SHAFT, WEST VULCAN.

BY CAPT. WM. BOND.

On March 14, 1890, the main shaft at West Vulcan was burned out. This was the pump shaft, and as a consequence the mine was flooded to within 40 feet of the surface. After the timbers burned out the shaft caved in from the sixth level up. This shaft had been located in the hanging slates, which were soft and heavy. The cost of repairing would have been large, and it would have been impossible to put it in such shape as not to require a large amount of money for maintaining it. After careful consideration, authority was given, June 1, to sink a new shaft. The new shaft was located 170 feet north and a like distance west of the burned shaft. It started from a hill-side on which the jasper formation outcropped, and was to pass down into the jasper slates which form the foot wall of the south formation. To reach the depth desired it was necessary to sink 1,000 feet.

It was to be vertical shaft. The dimensions adopted were 7 feet wide by 21½ feet long inside measurements. The shaft was made long and narrow and the long way of the shaft was set at right angles to the lay of the formation so as to cut the measures as little as possible, avoiding the difficulty we had had in the old shaft, and to facilitate the sinking. All the timber used was white and Norway pine except the wedges, which were partly maple. The sets were made of 14-inch square timbers 5 feet between centers, hung with 1¼-inch bolts and lathed around with 3-inch plank. The dividers were dovetailed into the wall plates, no spikes or staples being used. The shaft was divided into six compartments. A 14-inch square divider across the middle of the shaft divided it into nearly equal parts. The larger was devoted to the two hoisting compartments which were each 7 feet by 4 feet 9 inches, with a 10x14 inch divider between. The other half of the shaft was divided lengthways by a 12x14 inch divider into two compartments, one 10 feet by 3 feet 6 inches for the plunger pumps, and the other 10 feet by 2 feet 6 inches. This latter was again divided by a 6x14 inch divider into a timber cage compartment 6 feet by 2 feet 6 inches, and a ladder and pipe way 3 feet 6 inches by 2 feet 6 inches. A 6x14 inch divider was also set across the pump compartment opposite the divider between the ladder and timber compartments. The ladder way now contains, besides the vertical ladder, a 6-inch pipe for compressed air, a 6-inch steam pipe, and 8-inch water pipe for steam pumps, and a spare 4-inch pipe. The pump compartment contains two 13¼ inch square pump rods and an 18-inch water column between.

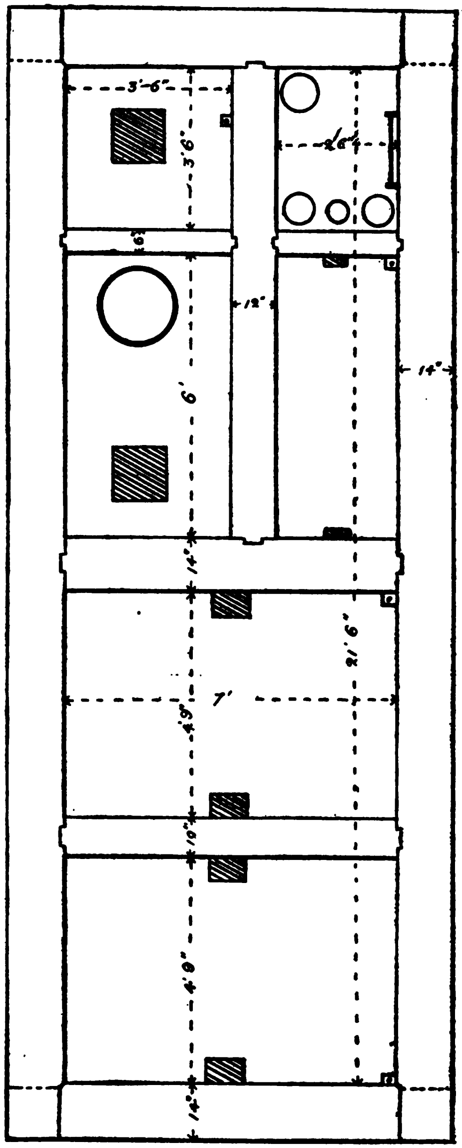
Ground was broken June 9th. The first work was cutting down the hillside for hitches for bearers, and excavating for the bob pit and pumping engine foundation. These were finished July 1st, and a derrick and a Rochester engine set up. By July 12 the shaft had been sunk 18 feet and built up above the bearers 20 feet to the landing brace. Regular sinking began on the 14th, and in the balance of the month 45 feet were sunk and timbered. This completed 83 feet of shaft in 26 working days.

On August 7th water was cut and a No. 6 Knowles pump was brought into use. Six days were lost between the 16th and 23d, in erecting the shaft house. Fifty-three feet were sunk and the second set of bearers put in in 20 working days. The depth of the shaft August 31 was 136 feet.

In September the shaft was sunk and timbered 72 feet in 26 working days which made it 208 feet deep.

By October 4th sheaves had been placed so as to bring ropes from the permanent hoisting engine with 12-foot drums. To one rope a cage was attached, to the other a fixed cross-head. Kibbles to hold one ton were hung from cage and cross-head on 15 feet of ¾-inch chain. The increase of water necessitated a larger pump and a No. 9 vertical Cameron was put in. This

PLAN OF 'C' SHAFT, WEST VULCAN



was attached to the rope of a Rochester engine so that it could be hoisted up out of the way at blasting time without delay. To facilitate this the discharge pipe was yoked to the hoisting rope and all that it was necessary to do was to disconnect the air hose and ring the bell, when discharge pipe, pump, suction hose and all would go up, to fall in place again at a moment's notice. Two days were lost in October by having to take down the compressed air pipe which was in the way of an engine house that had to be moved. This with the other delays made the sinking only 45 feet in 25 days. October 31 the shaft was 253 feet deep.

In November, election day and Thanksgiving day left only 23 working days, in which the shaft was sunk 61 feet, making it 314 feet deep.

In December the sinking was 74½ feet in 25 days, Christmas and the day after being holidays. The depth at the close of the year was 388½ feet.

The sixth level of the mine corresponds to a depth in "C" shaft of 406 feet. This was the level at which most of the water came in, and therefore a pair of 16-inch plungers was to be placed there. On January 2 began the work of making space on the north half of the west side of the shaft for these pumps. Beginning 28 feet above the level, offsets of 2 feet were made at each set for four sets, and this additional width of 8 feet in half the shaft was carried down to the point for the pump bearers. The shaft was sunk thus 39 feet in 12 working days. The balance of the month was used in cutting out a station on the east side 11 feet wide, 22 feet long and 8 feet high inside timbers, driving 6 feet in a drift east, cutting out a place for a tank west of the shaft below the level 10 feet wide, 10 feet long and 13 feet deep, cutting hitches and putting in bearers for the pumps.

In February straight work began again. The sinking was 72½ feet in 24 days, and the shaft men also drove 12 feet in the drift east. The shaft was then 500 feet deep—half way down.

On March 16th the pump compartment was covered with 12-

inch square timbers to prevent anything from falling on men below, and the work of lowering and placing the Cornish pumps was started. During the month the shaft was sunk 60 feet in 25 days, one day being lost—Good Friday.

April 29 was the day the Cornish pumps started to work. The time of putting them in was 39 days, with pitman and six men working in one shift of eight hours. The sinking in April was only 50 feet in 21 days, 120 hours being lost by the giving out of the sinking pumps. April 30 the shaft was 610 feet deep.

In May the shaft was sunk 74 feet and a set of bearers put in.

In June the shaft was sunk 83 feet in 26 days, making it 767 feet deep.

In July the sinking was 80 feet in 26 days, one day being lost, the Fourth of July.

August was the banner month, for in it the sinking was 109 feet in 28 days, including 2 days overtime. The 109 feet of shaft produced 3,997 kibbles of rock.

In September the shaft was sunk 74 feet, hitches were cut, and bearers put in at the twelfth level in 23 days. September 26, when sinking stopped, the shaft was 1,030 feet deep, completely timbered with cage roads and ladderway finished to the bottom.

The following table shows number of days worked, feet sunk, and average per day:

1890.	Days worked.	Feet sunk.	Average per day.
July	26	83	3 feet 2.3 inches.
August	20	53	2 " 7.8 "
September	26	72	2 " 9.2 "
October	25	45	1 " 9.6 "
November	23	61	2 " 7.8 "
December	25	74½	2 " 11.8 "
1891.			
January	12	39	3 " 3 "
February	24	72½	3 " .3 "
March	25	60	2 " 4.8 "
April	21	50	2 " 4.6 "
May	26	74	2 " 10.2 "
June	26	83	3 " 2.3 "

1891.	Days worked.	Feet sunk.	Average per day.
July	26	80	3 feet .9 inches.
August	28	109	3 " 10.7 "
September	23	74	3 " 2.6 "
	356	1,030	2 feet 10.7 inches.

This makes the average of a full month of 26 days 75 feet 2.7 inches. The actual time spent was nearly 15 months, or 68 feet 8 inches per month.

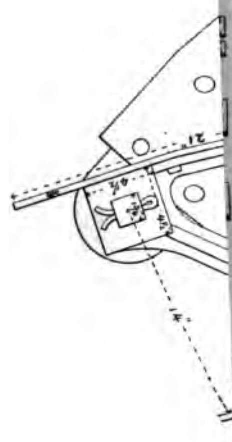
The working force was divided into three eight-hour shifts.

The drill shift was composed of 16 men, a boss and pump man—18 in all. Eight 3½-inch Sergeant drills on four shaft bars were used. This shift would drill the shaft over and blast 15 to 20 holes in the sink, leaving the holes in the ends plugged with wood, to be blasted on the next shift. The blasting was all done with a battery, and considerable difficulty was had in getting a battery to put off all the holes at once. On the mucking shift there were 11 men, a boss and pump man. These would hoist the rock from the sink until lunch time, when one of the men would charge and blast the holes that had been left. Then the men returned and hoisted rock again the rest of their time. There was one less man on the timber shift than on the mucking shift. This shift would put in a set of timbers when there was room for it and then clear up any rock left by the other shift. When there was no room for another set, they would clean up the shaft and then put in cage runners and ladderways and plank up between dividers, always leaving the shaft ready for the drill shift. The total number of men was 43, including 3 bosses and 3 pump men.

While the shaft was being sunk the mine was being unwatered. This was a very tedious work, as there was but a small double-track skip shaft that could be used. The mine made about 400 gallons of water, most of it coming in at the sixth level. After this had been drawn to the plungers in the new shaft, unwatering the rest was less difficult. The pumps used were a special No. 10 Cameron, a Worthington fire pump and two No. 10 Knowles.

After the sinking had been finished, stations were cut at the eleventh and twelfth levels and cross-cuts driven to connect with the mine. Connection was made on the eleventh level December 2, and ore hoisted nine days later.

From breaking ground, June 9, 1890, until the Cornish pumps were working from the bottom, February 15, 1892, was a little over 20 months. During this time 1,030 feet of shaft were sunk, three large stations cut, 628 feet of drifts made, a pair of 16 and two pairs of 12-inch Cornish plungers put in and set working, thus placing the mine in excellent shape to resume its former position as a producer.



A POCKET STOP.

BY WILLIAM KELLY.

From a certain standpoint, business seems to be an aggregation of details. It needs no apology, therefore, to present to the Institute a drawing and description of a device to facilitate one of the minor operations in the handling of mine products. The easy control of ore, coal or rock passing through a chute is the advantage claimed for this pocket stop. We are indebted to Mr. Larsson for the introduction of this stop, the idea of which comes from the north of England.

On the drawing, the stop is represented in three figures. The top one is a side elevation, showing a part of the chute with the stop open. The middle view is a longitudinal section or vertical section through the axis of the chute. In this figure the stop is closed. The bottom one is an end view looking upwards at an angle of 45° through the chute with the stop open.

The apparatus consists of a handle, an axle, two castings in the form of quadrants, two plates of steel and two hangers.

As we have it in use at Vulcan, the handle is a lever about 4′ 6″ long with a square eye to fit the axle. The handle is at an angle of about 30° with the top plate, so as to be within reach of the arm of a man standing at the side of the chute. When the stop is open, the lever is prevented from going too far by an iron fastened to the side of the chute, shown in figure 3. When the stop is closed, the end of the handle lies against a block of wood not shown.

The axle is a bar of iron 1¾″ square, turned round where it rests on the hangers.

The hub of the castings is a cube 4½″ each way, cored out to fit the axle. The rim covers about 60° of the circumference of a circle 14″ in radius. The edges of the upper arm and rim are 4½″ wide, strengthened by a web 1″ wide and ¾″ deep. The castings are held in place on the axle by two split keys.

The upper plate is flat. It measures 26¼″x 21″x ⅜″. It extends beyond the hub 4¼″. The curved plate is 26¼″x 24″x ⅜″. Plates ½″ thick would be better. These plates are riveted to the upper arm and rim of the castings, the edges being set flush. The rivets are counter sunk.

The hangers are made of straps 2½″x ½″, bent in the form of a U. They are bolted to the side plates of the chute.

These side plates, as in figure 1, extend beyond the chutes proper 9″. For two feet from the end, the chute is covered with plank.

When the stop is open, the top plate is flat with the bottom of the chute. When shut, the ore is choked between the top of the stop and the plank above. The stop does not completely close the chute, which is unnecessary with our ores, and being small, it is easily handled. If the ore were soft and wet it might be necessary to have it close completely.

The cost of the stop put in place is between $20 and $25.

This stop is especially adapted for a chute which is not often emptied. In dumping ore into an empty chute large lumps may bend the plates. It is best to keep a little ore on the stop. For this reason it is not particularly adapted to dock pockets, but it answers excellently for mine pockets, and may be used advantageously underground where considerable material is to pass through it and the space permits.